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AN ATLAS OF ACTIVATED SLUDGE TYPES

Wesley O. Pipes

Northwestern University
Evanston, Illinois

December 1968

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EVANSTON, ILLINOIS

AN ATLAS OF ACTIVATED SLUDGE TYPES

by

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Grant No. WP-00588-04
Federal Water Pollution Control Administration
U.S. Department of the Interior

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December 1968

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THE ATLAS

Plant Location West Chicago, Ill. #3 Date September 22, 1966

I. Microscopic Observations

		Particles	Filaments
A.	Distribution	geometric normal	geometric normal
B.	Geometric mean	4900 μ^2	11,000 μ^2
C.	Standard deviation	2.8	2.6
D.	No. counted per ml.	618,000	greater than 2,800,000
E.	No. counted per gm.	172,000	720,000

F. Types of protozoans - numerous stalked ciliates and flagellates; rare amoebas and free swimming ciliates.

G. Types of invertebrates - numerous rotifers.

H. Other observations - compact, filamentous floc particles; moderate concentration of dispersed material; rare fungal filaments.

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus

B. Present in small numbers - Actinomycetales, one unidentified bacterium.

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 52

B. Compaction rate (mls/minute) 0.91

C. Sludge Volume Index (mls/gm) 93

IV. Plant performance as indicated by:

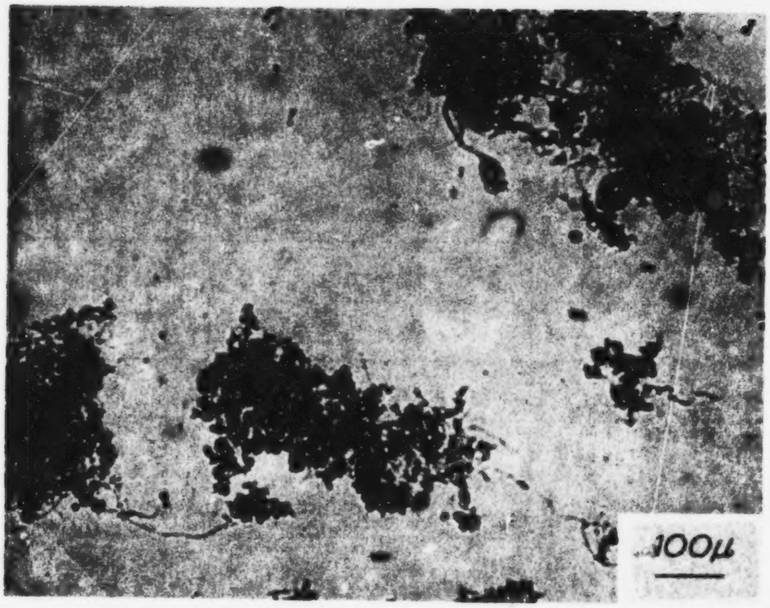
A. Loading 0.084 $\frac{\text{lbs BOD/day}}{\text{lbs MLSS}}$

B. Effluent BOD 13 mg/l

C. BOD reduction 87%

D. Type of waste - domestic and industrial (including food processing)

E. Special problems - bulking and deflocculation have been experienced since the food processing plant began operation in 1963.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Plant Location West Chicago, Ill. #5

Date October 6, 1966

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	6800 μ^2	5900 μ^2
C. Standard deviation	2.4	2.3
D. No. counted per ml.	340,000	1,680,000
E. No. counted per gm.	142,000	690,000

F. Types of protozoans - rare stalked ciliates; numerous flagellates and amoebas.

G. Types of invertebrates - rare rotifers

H. Other observations - compact, moderately filamentous sludge particles; moderate concentration of dispersed material; rare spirochaetes.

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus

B. Present in small numbers - Actinomycetales

III. Settling characteristics of the sludge

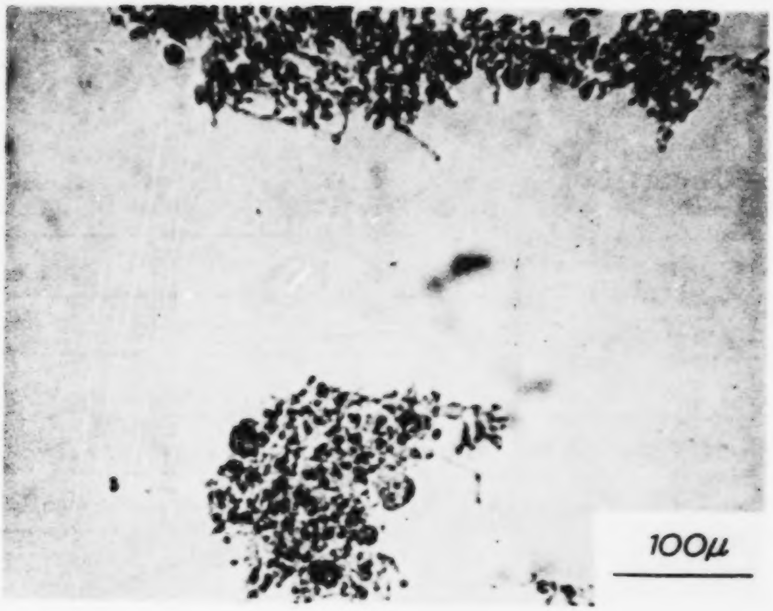
A. Settling rate (mls/minute) 226
B. Compaction rate (mls/minute) 0.45
C. Sludge Volume Index (mls/gm) 77

IV. Plant performance as indicated by:

A. Loading 0.303 $\frac{\text{lbs BOD/day}}{\text{lb. MLSS}}$
B. Effluent BOD 26 mg/l
C. BOD reduction 89%

D. Type of waste - domestic and industrial (includes food processing)

E. Special problems - bulking and deflocculation have been experienced since a food processing plant began operation in 1963.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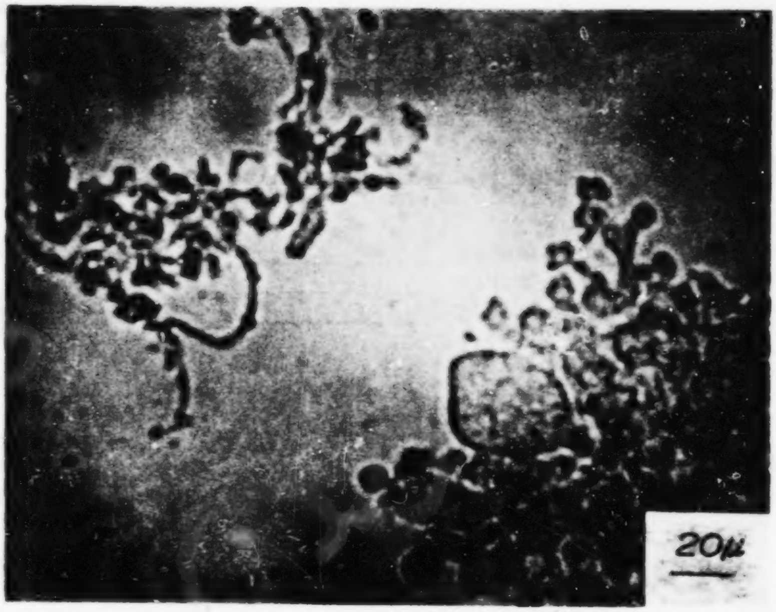
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Plant Location **West Chicago, Ill. #23** Date **May 25, 1967**

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	4800 μ^2	8800 μ^2
C. Standard deviation	2.5	2.1
D. No. counted per ml.	498,000	1,248,000
E. No. counted per gm.	193,000	490,000

F. Types of protozoans - **numerous stalked ciliates and flagellates**

G. Types of invertebrates- **rare rotifers**

H. Other observations - **medium to high density floc particles with many long filaments; moderate amount of dispersed material**

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - **Bacillus**

B. Present in small numbers - **Actinomycetales, one unidentified bacterium.**

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) **20**
B. Compaction rate (mls/minute) **2.40**
C. Sludge Volume Index (mls/gm) **223**

IV. Plant performance as indicated by:

A. Loading **0.206** $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD **11 mg/1**
C. BOD reduction **94%**

D. Type of waste- **domestic and industrial (includes food processing)**

E. Special problems - **bulking and deflocculation have been experienced since a food processing plant began operation in 1963.**

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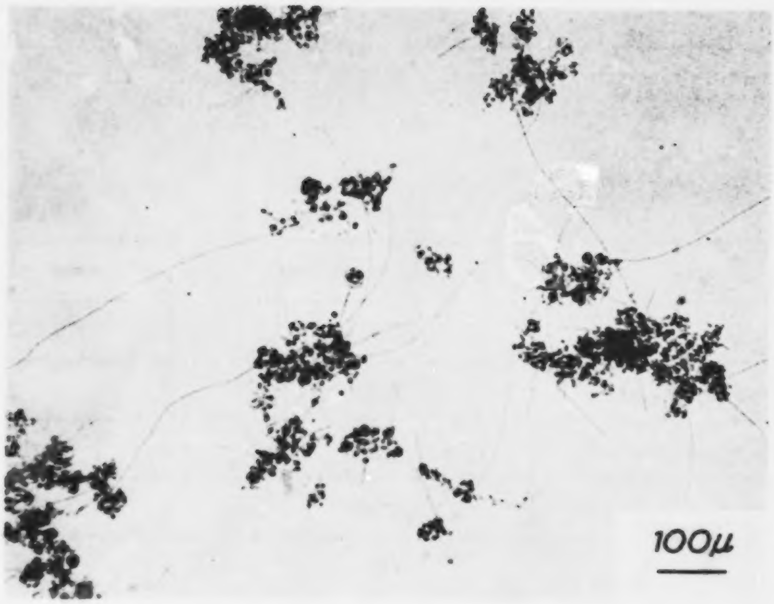


Plant Location West Chicago, Ill. #44

Date January 18, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	5800 μ^2	11,300 μ^2
C. Standard deviation	2.2	2.1
D. No. counted per ml.	1,940,000	2,780,000
E. No. counted per gm.	232,000	330,000

F. Types of protozoans - numerous stalked ciliates, amoebas, and free swimming ciliates; rare flagellates.

G. Types of invertebrates - none observed

H. Other observations - medium density floc particles of various sizes and with many filaments; moderate concentration of dispersed material; rare spirochaetes; small zoogleal colonies rarely seen.

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Arthrobacter

B. Present in small numbers - Actinomycetales

III. Settling characteristics of the sludge

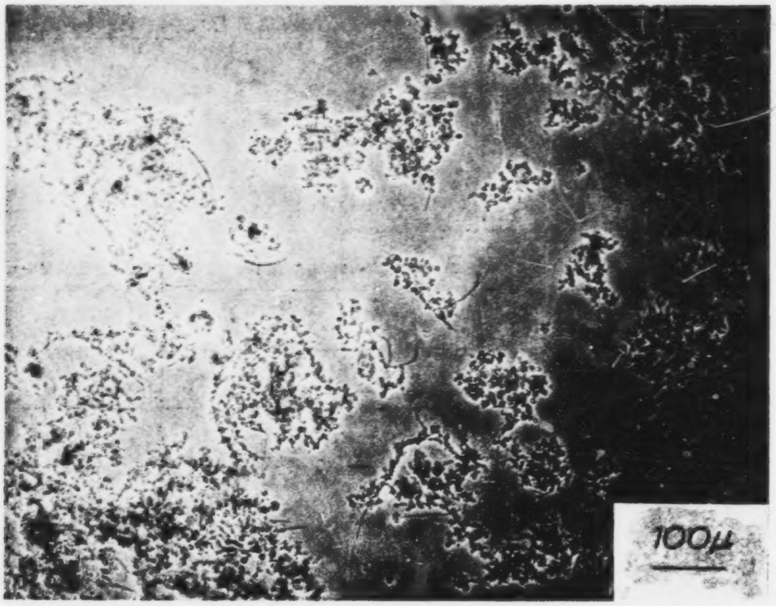
A. Settling rate (mls/minute) 9
B. Compaction rate (mls/minute) 2.80
C. Sludge Volume Index (mls/gm) 108

IV. Plant performance as indicated by:

A. Loading 0.122 $\frac{\text{lbs BOD/Day}}{\text{lb MLSS}}$
B. Effluent BOD 33 mg/1
C. BOD reduction 90%

D. Type of waste domestic and industrial (includes food processing)

E. Special problems - very high solids in mixed liquor aeration tank; bulking and deflocculation have been experienced since a food processing plant began operation in 1963.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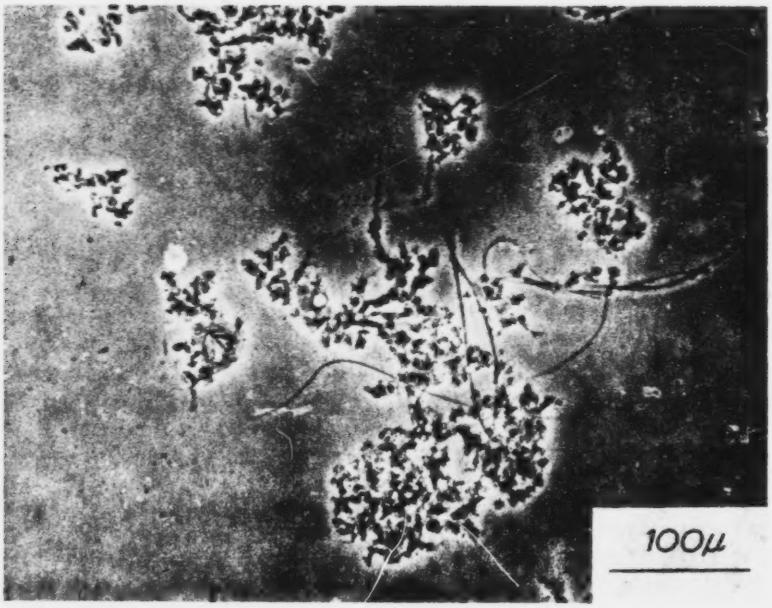
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Plant Location Chicago, N.S., Ill. #6 Date October 13, 1966

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	7200 μ^2	7300 μ^2
C. Standard deviation	2.6	2.6
D. No. counted per ml.	310,000	2,510,000
E. No. counted per gm.	117,000	940,000

F. Types of protozoans - rare stalked ciliates; numerous flagellates and amoebas

G. Types of invertebrates - rare rotifers

H. Other observations - compact floc particles with many filaments; moderate amount of dispersed material; numerous spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - None

B. Present in small numbers - Bacillus, Actinomycetales, Beggiatoa

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 87
B. Compaction rate (mls/minute) 1.25
C. Sludge Volume Index (mls/gm) 125

IV. Plant performance as indicated by:

A. Loading 0.1 $\frac{\text{lbs. BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 14 mg/1
C. BOD reduction 87%

D. Type of waste - domestic and industrial

E. Special problems - a history of bulking in late summer or early fall

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Plant Location Chicago, N.S., Ill. #30 Date August 8, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	10,000 μ^2	19,000 μ^2
C. Standard deviation	2.4	2.5
D. No. counted per ml.	225,000	1,480,000
E. No. counted per gm.	82,000	540,000

F. Types of protozoans - numerous stalked ciliates, flagellates and amoebas; rare free swimming ciliates

G. Types of invertebrates - numerous rotifers

H. Other observations - medium to high density floc particles of various sizes and with many small filaments; medium concentration of dispersed material; rare spirochaetes and zoogleal formation

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Beggiatoa

B. Present in small numbers - Actinomycetales

III. Settling characteristics of the sludge

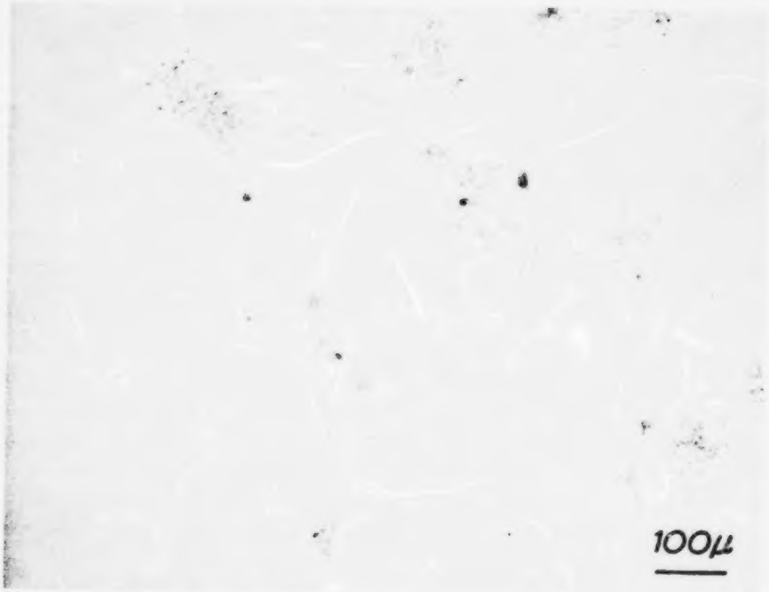
A. Settling rate (mls/minute) 315
B. Compaction rate (mls/minute) 0.67
C. Sludge Volume Index (mls/gm) 80

IV. Plant performance as indicated by:

A. Loading 0.151 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 12 mg/l
C. BOD reduction 89%

D. Type of waste - domestic and industrial

E. Special problems - history of bulking in late summer or early fall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Plant Location Chicago, N.S., Ill., #48

Date February 15, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	$4,100\ \mu^2$	$7,700\ \mu^2$
C. Standard deviation	2.2	2.0
D. No. counted per ml.	975,000	475,000
E. No. counted per gm.	272,000	130,000

F. Types of protozoans - numerous stalked ciliates and amoebas; rare flagellates and free swimming ciliates

G. Types of invertebrates - numerous rotifers

H. Other observations - compact floc particles of various size with much fibrous material; moderate concentration of dispersed material; rare fungal filaments; numerous spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Actinomycetales

B. Present in small numbers - Bacillus, Beggiatoa

III. Settling characteristics of the sludge

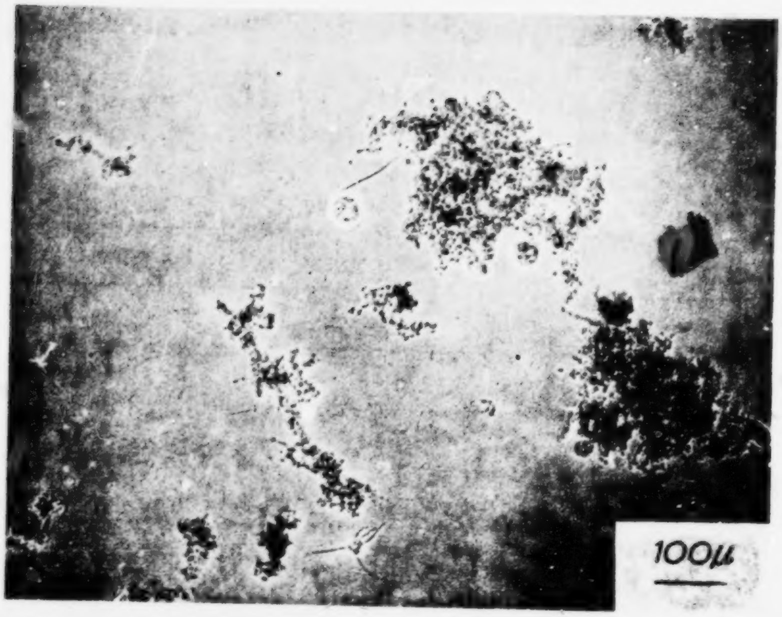
A. Settling rate (mls/minute) 132
B. Compaction rate (mls/minute) 0.91
C. Sludge Volume Index (mls/gm) 78

IV. Plant performance as indicated by:

A. Loading 0.096 $\frac{\text{lbs. BOD/day}}{\text{lb. MLSS}}$
B. Effluent BOD 13 mg/1
C. BOD reduction 86%

D. Type of waste - domestic and industrial

E. Special problems - history of bulking in late summer or early fall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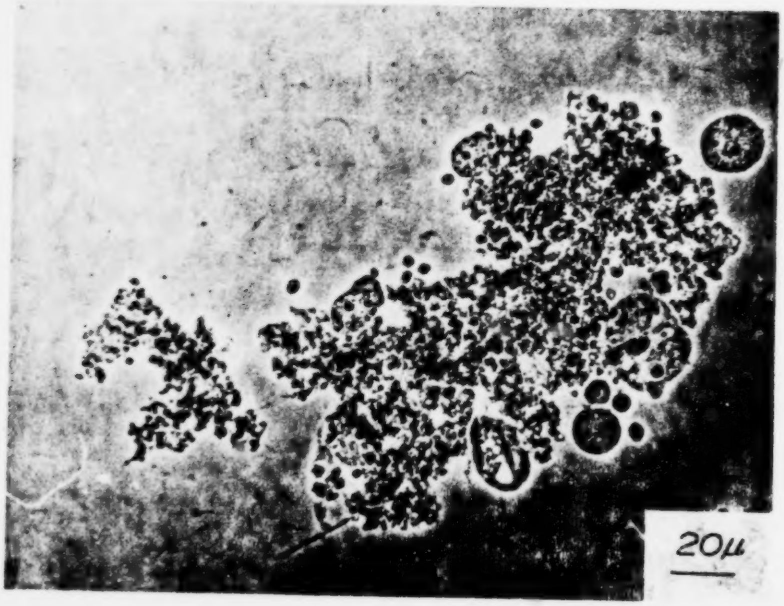
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Plant Location Chicago, N.S., Ill. #55 Date April 18, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	3,800 μ^2	7,650 μ^2
C. Standard deviation	2.4	2.2
D. No. counted per ml.	615,000	515,000
E. No. counted per gm.	227,000	190,000

F. Types of protozoans numerous stalked ciliates, flagellates, amoebas and free swimming ciliates

G. Types of invertebrates - numerous rotifers

H. Other observations - compact sludge particles with few filaments and some debris (cellulose, etc.) moderate concentration of dispersed material; rare fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - none

B. Present in small numbers - Bacillus, Actinomycetales, Sphaerotilus

III. Settling characteristics of the sludge

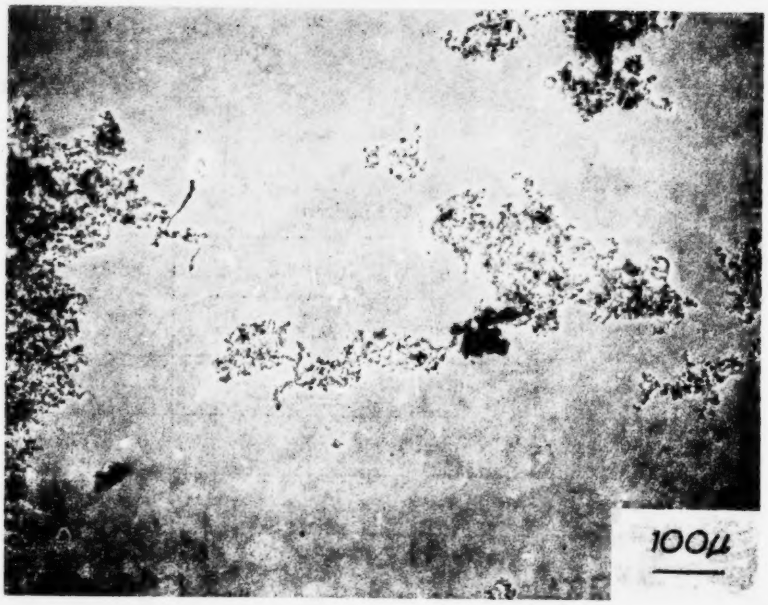
A. Settling rate (mls/minute) 237
B. Compaction rate (mls/minute) 0.81
C. Sludge Volume Index (mls/gm) 84

IV. Plant performance as indicated by:

A. Loading 0.098 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 4 mg/l
C. BOD reduction 94%

D. Type of waste - domestic and industrial

E. Special problems- history of bulking in late summer or early fall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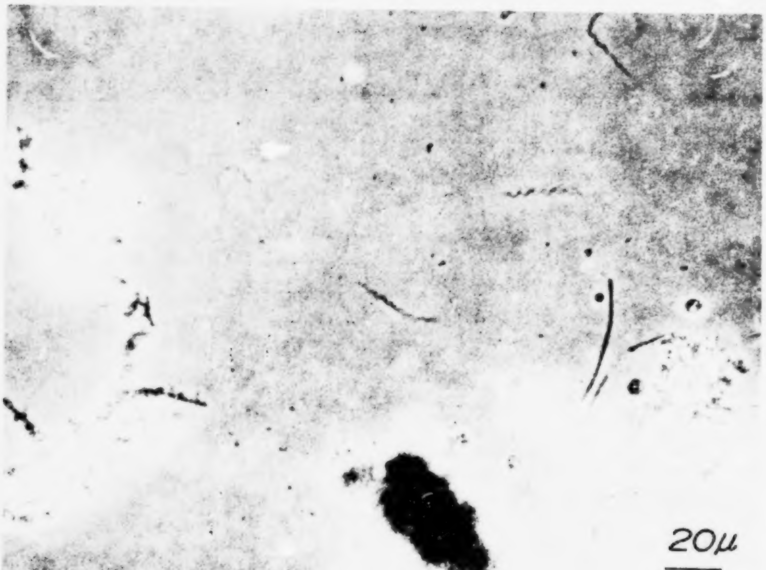
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Plant Location Fort Wayne, Indiana, #7 Date October 20, 1966

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	6,200 μ^2	36,000 μ^2
C. Standard deviation	8.0	2.8
D. No. counted per ml.	127,000	3,120,000
E. No. counted per gm.	49,000	1,200,000

F. Types of protozoans - numerous stalked ciliates, flagellates, and amoebas

G. Types of invertebrates - numerous rotifers

H. Other observations - medium density, highly filamentous floc particles; moderate concentration of dispersed material; numerous spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus

B. Present in small numbers - Actinomycetales, Sphaerotilus

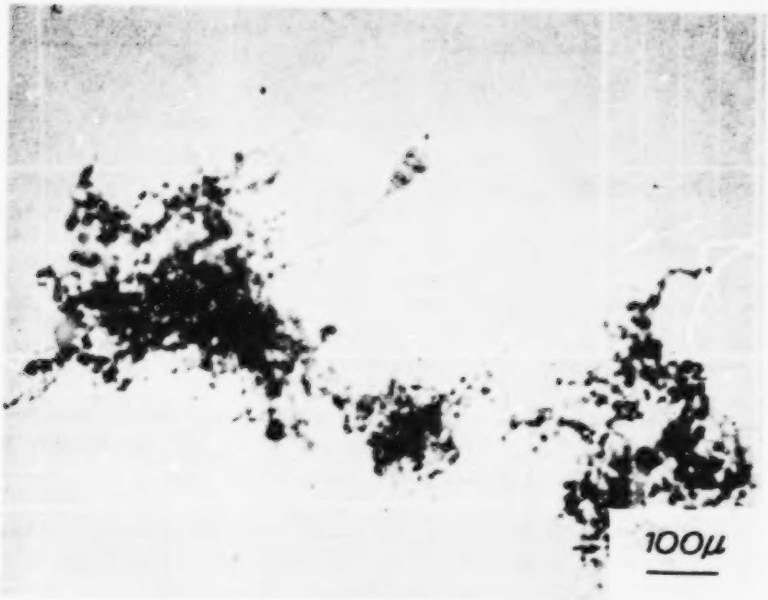
III. Settling characteristics of the sludge

A. Settling rate (mls/minute) --
B. Compaction rate (mls/minute) 2.34
C. Sludge Volume Index (mls/gm) 346

IV. Plant performance as indicated by:

A. Loading 0.165 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 6 mg/l
C. BOD reduction 97%

D. Type of waste--domestic and industrial (solvents, cresylic acid and brewery waste)
E. Special problems- chronic bulking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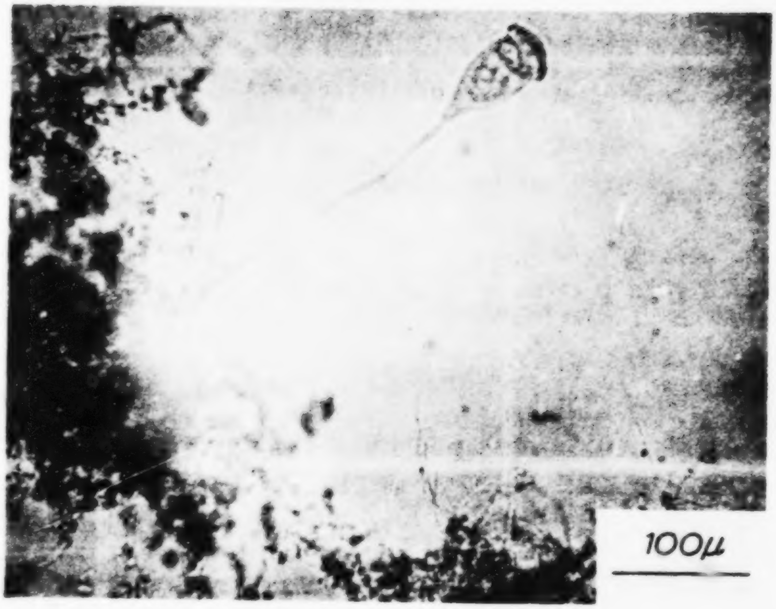
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Plant Location **Fort Wayne, Indiana, #21** Date **April 27, 1967**

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	5,900 μ^2	30,000 μ^2
C. Standard deviation	5.3	3.2
D. No. counted per ml.	352,000	3,080,000
E. No. counted per gm.	165,000	1,450,000

F. Types of protozoans - **numerous stalked ciliates and amoebas; rare flagellates**

G. Types of invertebrates - **numerous rotifers**

H. Other observations - **highly filamentous floc particles of low to medium density; moderate concentration of dispersed material; rare fungal filaments and spirochaetes**

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - **Bacillus**

B. Present in small numbers - **Actinomycetales**

III. Settling characteristics of the sludge

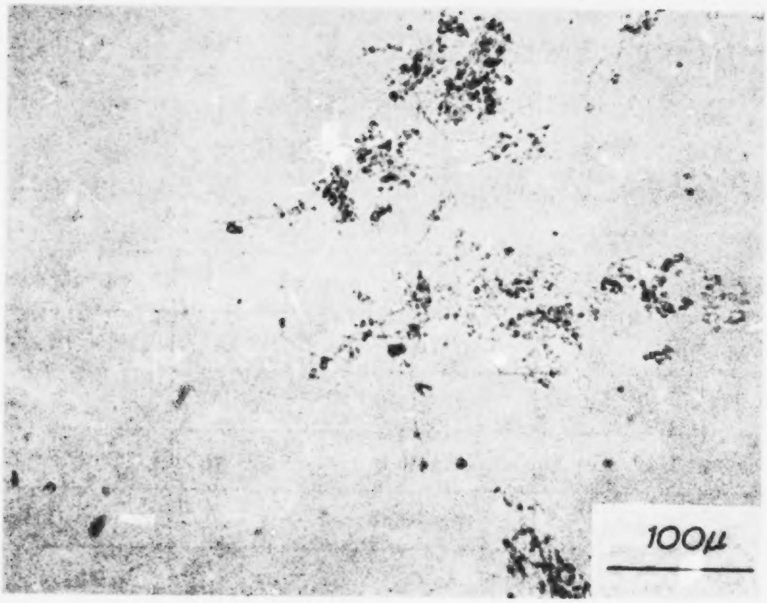
A. Settling rate (mls/minute) 7
B. Compaction rate (mls/minute) 3.90
C. Sludge Volume Index (mls/gm) 412

IV. Plant performance as indicated by:

A. Loading **0.138** $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD **17 mg/l**
C. BOD reduction **86%**

D. Type of waste - **domestic and industrial (solvents, cresylic acid, and brewery waste)**

E. Special problems - **chronic bulking**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Plant Location Fort Wayne, Indiana, #50 Date March 8, 1968

I. Microscopic Observations

		Particles	Filaments
A.	Distribution	geometric normal	geometric normal
B.	Geometric mean	4,800 μ^2	11,400 μ^2
C.	Standard deviation	2.5	2.4
D.	No. counted per ml.	683,000	750,000
E.	No. counted per gm.	309,000	340,000

F. Types of protozoans - numerous stalked ciliates, flagellates, and amoebas; rare free swimming ciliates

G. Types of invertebrates- rare rotifers

H. Other observations - medium to high density floc particles of various sizes and few filaments; moderate concentration of dispersed materials

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Actinomycetales, Arthrobacter, Brevibacterium

B. Present in small numbers - Bacillus, unidentified bacterium

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 80
B. Compaction rate (mls/minute) 1.50
C. Sludge Volume Index (mls/gm) 139

IV. Plant performance as indicated by:

A. Loading 0.177 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 28 mg/l
C. BOD reduction 83%

D. Type of waste - domestic and industrial (solvents, cresylic acid, and brewery wastes)

E. Special problems - chronic bulking

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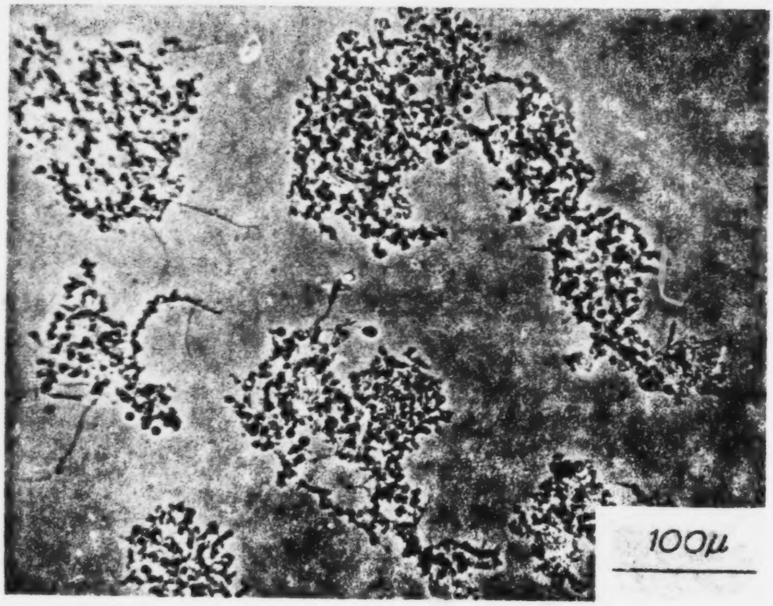
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Plant Location Fort Wayne, Indiana, #64 Date August 1, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	nongeometric	nongeometric
B. Geometric mean	4,530 μ^2	10,300 μ^2
C. Standard deviation	2.73	2.57
D. No. counted per ml.	578,000	3,260,000
E. No. counted per gm.	240,000	1,350,000

F. Types of protozoans - numerous flagellates and amoebas; rare stalked ciliates

G. Types of invertebrates - numerous rotifers

H. Other observations - medium density floc particles with many filaments; moderate concentration of dispersed material; very rare zoogleal formation

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Arthrobacter

B. Present in small numbers - Actinomycetales. Sphaerotilus

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 65

B. Compaction rate (mls/minute) 1.60

C. Sludge Volume Index (mls/gm) 119

IV. Plant performance as indicated by:

A. Loading $0.068 \ \frac{\text{lbs BOD/day}}{\text{lb MLSS}}$

B. Effluent BOD 5.88 mg/l

C. BOD reduction 92%

D. Type of waste - domestic and industrial (solvents, cresylic acid, and brewery waste)

E. Special problems - chronic bulking; increased flow due to rain on the night previous to sampling; black sludge in raw sewage but not yet in primary clarifier

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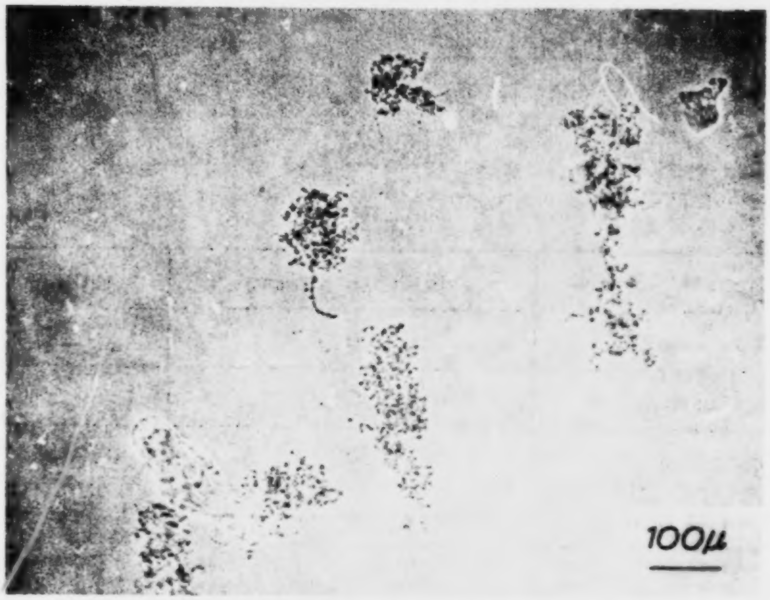
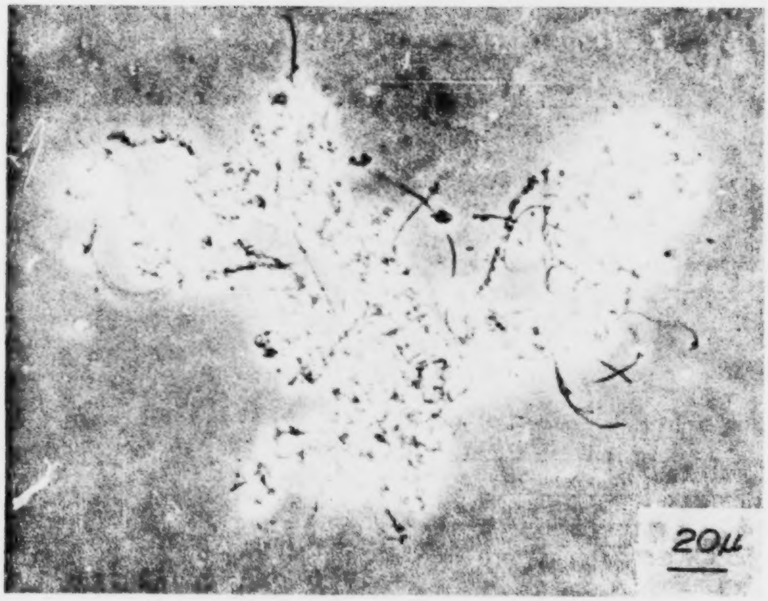




Plant Location McHenry, Illinois, #8 Date October 27, 1966

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	6,100 μ^2	10,000 μ^2
C. Standard deviation	2.3	2.3
D. No. counted per ml.	522,000	1,345,000
E. No. counted per gm.	118,000	300,000

F. Types of protozoans - rare stalked ciliates; numerous flagellates and amoebas

G. Types of invertebrates - none observed

H. Other observations - compact floc particles with few filaments; moderate concentration of dispersed material

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - None

B. Present in small numbers - Bacillus, Actinomycetales, Sphaerotilus

III. Settling characteristics of the sludge

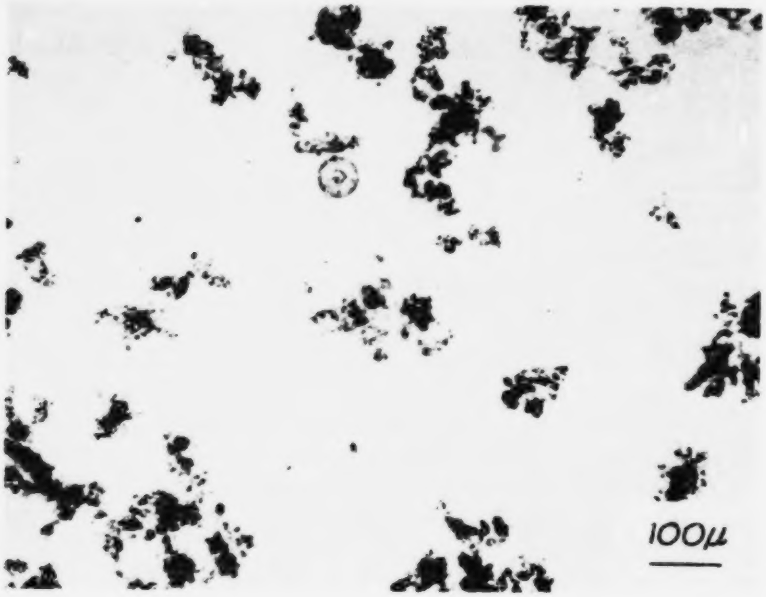
A. Settling rate (mls/minute) 60
B. Compaction rate (mls/minute) 1.14
C. Sludge Volume Index (mls/gm) 78

IV. Plant performance as indicated by:

A. Loading 0.094 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$.
B. Effluent BOD 62 mg/l
C. BOD reduction 69%

D. Type of waste - domestic and industrial (includes feed mill, wax factory, and radio factory)

E. Special problems - periodic problems with waste from wax factory and feed mill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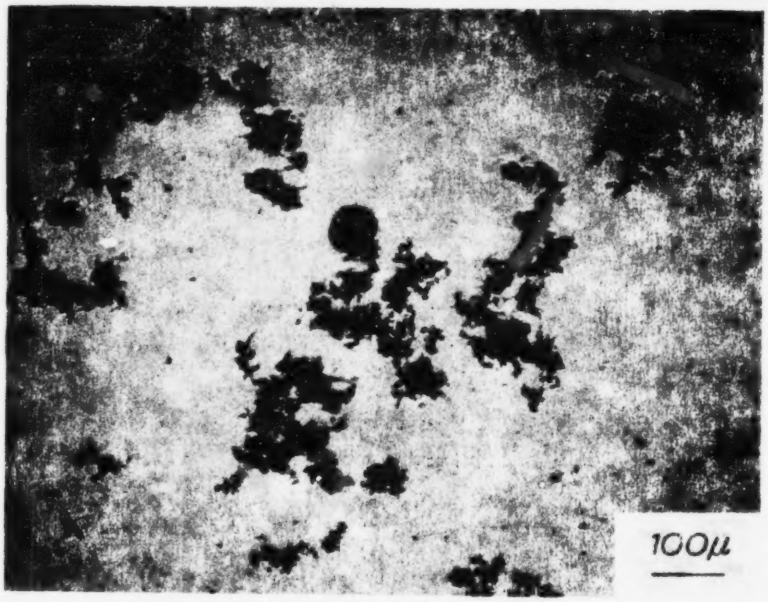
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Plant Location McHenry, Illinois, #28 Date July 25, 1967

I. Microscopic Observations

		Particles	Filaments
A.	Distribution	geometric normal	geometric normal
B.	Geometric mean	3,600 μ^2	8,200 μ^2
C.	Standard deviation	3.0	2.3
D.	No. counted per ml.	750,000	4,468,000
E.	No. counted per gm.	457,000	2,730,000

F. Types of protozoans - rare flagellates and amoebas

G. Types of invertebrates - numerous rotifers

H. Other observations - low to medium density of floc particles with numerous filaments; moderate concentration of dispersed material; rare spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Sphaerotilus

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

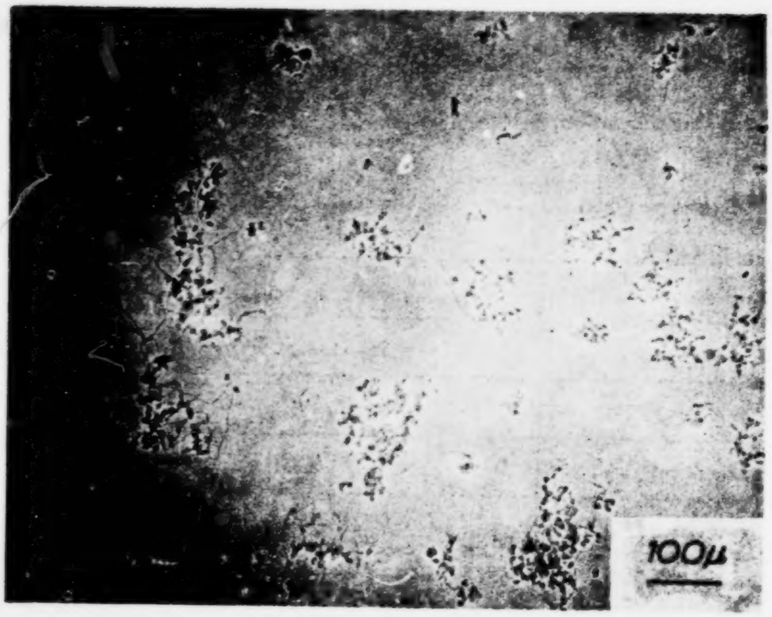
A. Settling rate (mls/minute) --
B. Compaction rate (mls/minute) 2.50
C. Sludge Volume Index (mls/gm) 547

IV. Plant performance as indicated by:

A. Loading 0.093 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 27 mg/l
C. BOD reduction 63%

D. Type of waste - domestic and industrial (includes feed mill, wax factory, and radio factory)

E. Special problems - periodic problems with waste from wax factory and feed mill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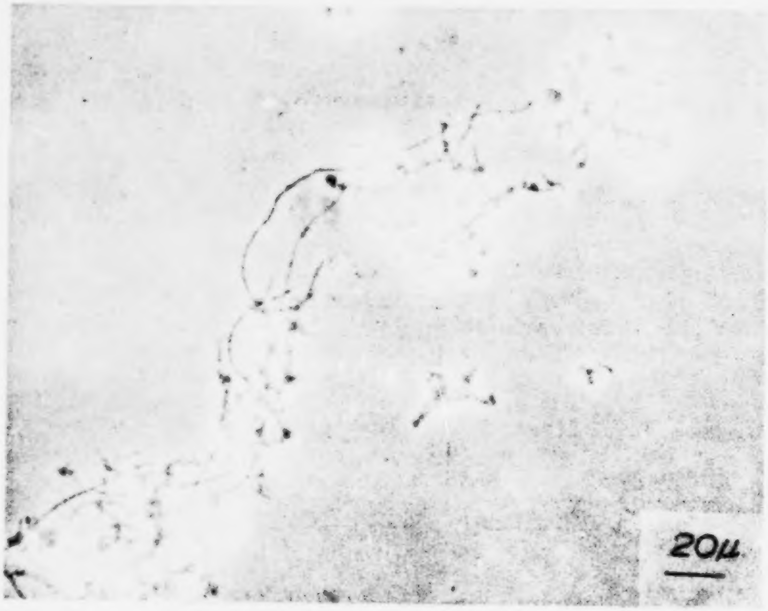
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Plant Location McHenry, Illinois, #46 Date February 1, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	6,100 μ^2	11,200 μ^2
C. Standard deviation	2.1	1.8
D. No. counted per ml.	883,000	103,000
E. No. counted per gm.	315,000	40,000

F. Types of protozoans - numerous free swimming ciliates; rare amoebas

G. Types of invertebrates - none observed

H. Other observations - compact floc particles with ragged edges and few filaments, medium concentration of dispersed material; rare zoogleal formation

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus

B. Present in small numbers - Actinomycetales

III. Settling characteristics of the sludge

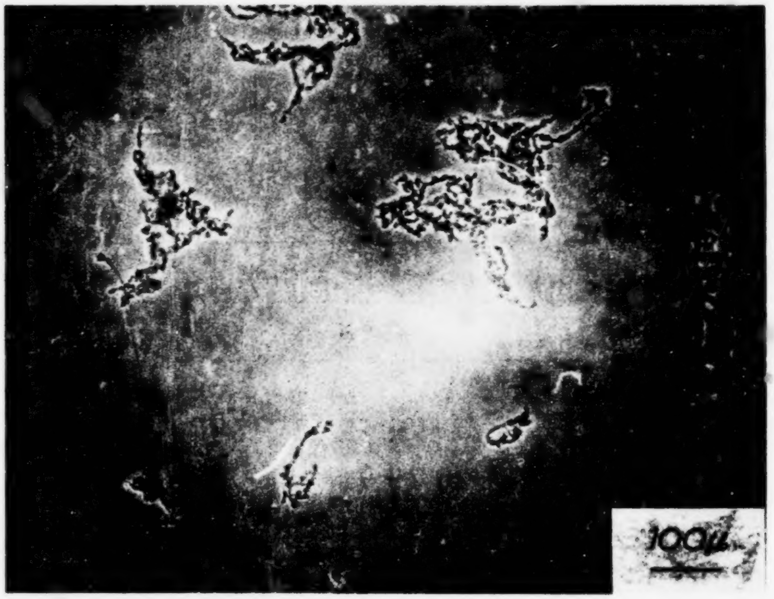
A. Settling rate (mls/minute) 130
B. Compaction rate (mls/minute) 0.77
C. Sludge Volume Index (mls/gm) 83

IV. Plant performance as indicated by:

A. Loading 0.087 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 25 mg/l
C. BOD reduction 79%

D. Type of waste - domestic and industrial (includes feed mill, wax factory and radio factory)

E. Special problems - periodic problems with waste from wax factory and feed mill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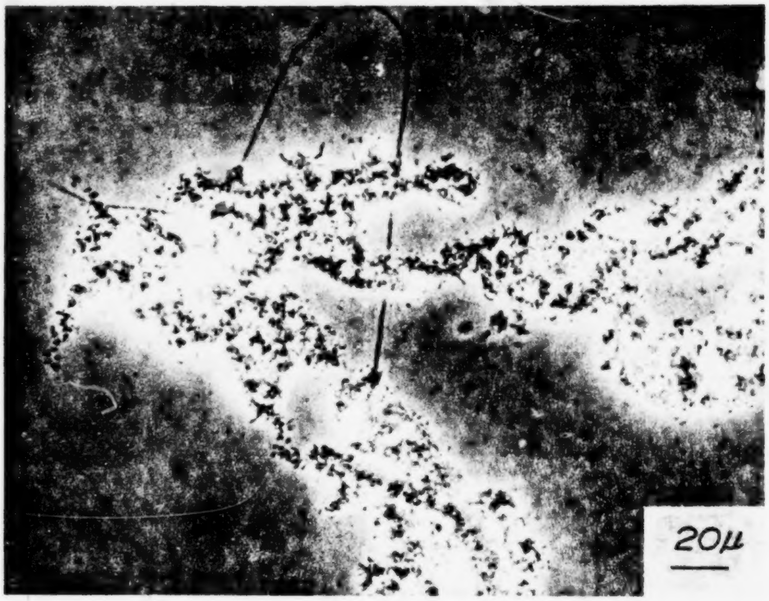
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Plant Location McHenry, Illinois, #53 Date April 4, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	7,600 μ^2	28,000 μ^2
C. Standard deviation	2.8	3.2
D. No. counted per ml.	98,000	253,000
E. No. counted per gm.	127,000	50,000

F. Types of protozoans - **numerous flagellates**

G. Types of invertebrates - **none observed**

H. Other observations - **ragged floc particles with medium density, few long filaments and of different sizes; floc appears to disperse quite easily**

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - **Arthrobacter**

B. Present in small numbers - **Bacillus, Actinomycetales**

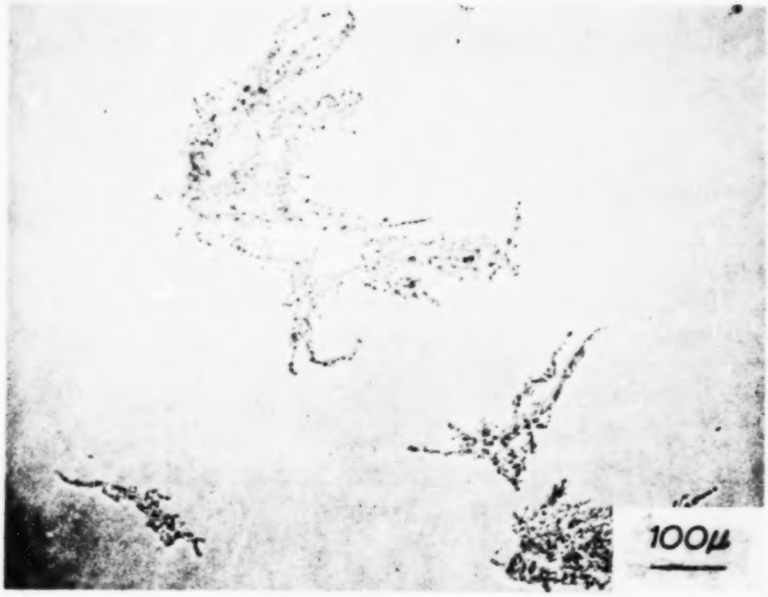
III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 195
B. Compaction rate (mls/minute) 1.00
C. Sludge Volume Index (mls/gm) 100

IV. Plant performance as indicated by:

A. Loading $0.173 \; \frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 27 mg/1
C. BOD reduction 84%

D. Type of waste - **domestic and industrial (includes feed mill, wax factory and radio factory)**
E. Special problems - **periodic problems with waste from wax factory and feed mill**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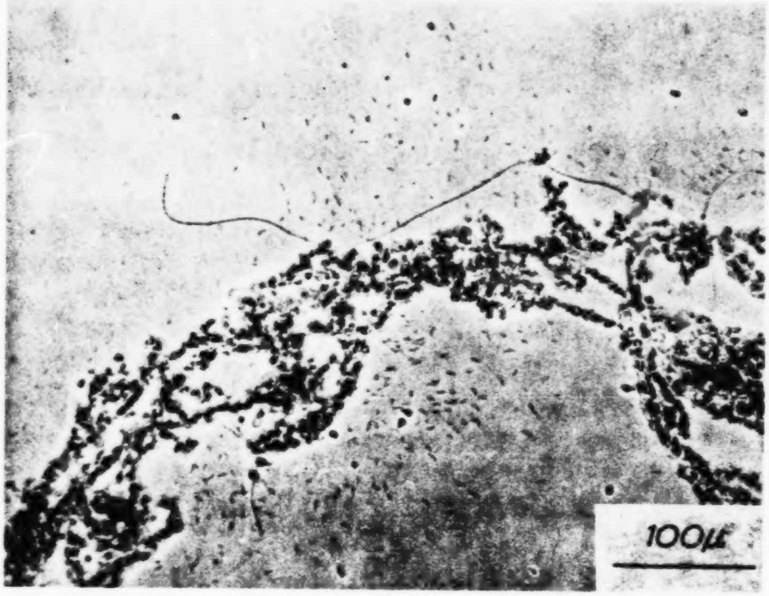
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Plant Location Milton, Wisconsin, #9   Date November 3, 1966

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	insufficient data
B. Geometric mean	3,300 μ^2	insufficient data
C. Standard deviation	3.2	insufficient data
D. No. counted per ml.	36,000	greater than 63,000
E. No. counted per gm.	53,000	greater than 90,000

F. Types of protozoans - numerous stalked ciliates and flagellates; rare amoebas

G. Types of invertebrates - none observed

H. Other observations - many large, filamentous floc particles with ragged edges; medium concentration of dispersed material including isolated filamentous bacteria

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Beggiatoa

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

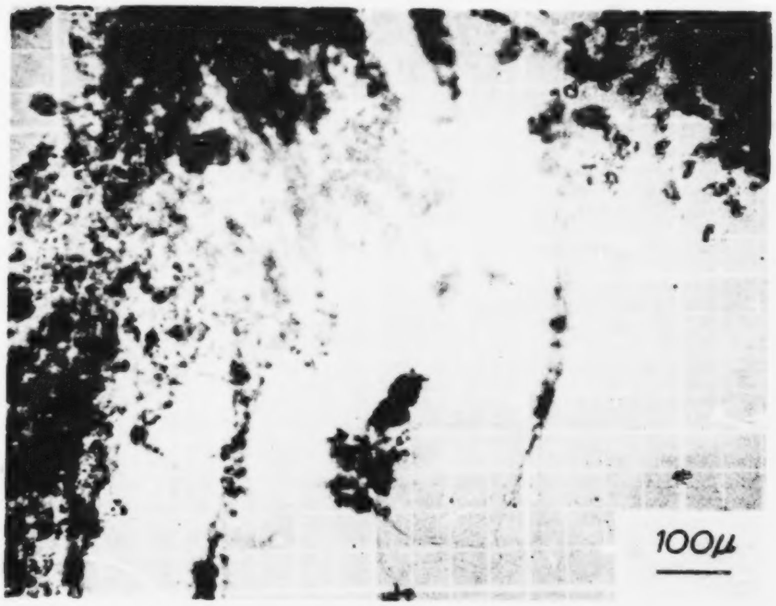
A. Settling rate (mls/minute) 880
B. Compaction rate (mls/minute) 0.11
C. Sludge Volume Index (mls/gm) 82

IV. Plant performance as indicated by:

A. Loading $0.783 \; \frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 70 mg/1
C. BOD reduction 74%

D. Type of waste - domestic and industrial (includes wash water from milk receiving plant)

E. Special problems - loss of solids from secondary clarifier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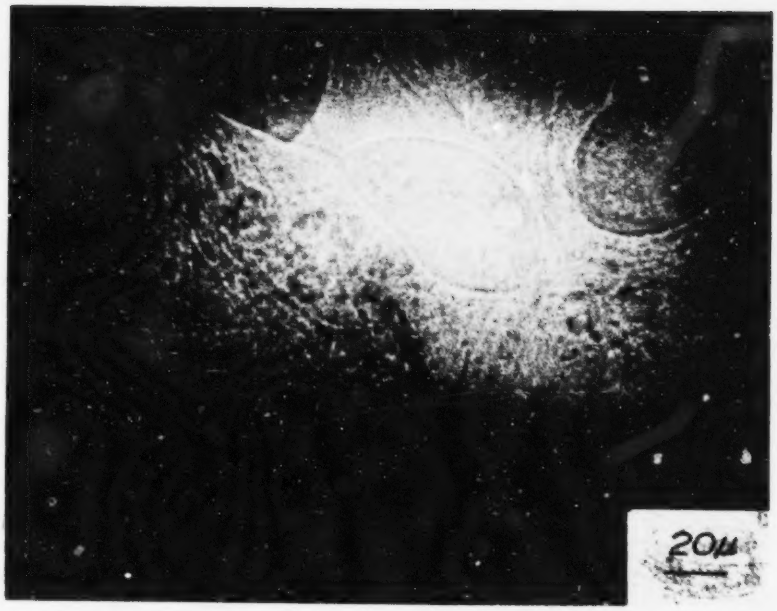
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Plant Location Milton, Wisconsin, #22 Date May 11, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	$3{,}000\mu^2$	--
C. Standard deviation	9.0	--
D. No. counted per ml.	47,300	94,200
E. No. counted per gm.	57,000	110,000

F. Types of protozoans - numerous stalked ciliates and flagellates

G. Types of invertebrates - none observed

H. Other observations- many large to medium size, ragged and filamentous floc particles. Floc is low to medium density, medium concentration of dispersed material; rare fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - none

B. Present in small numbers - Bacillus, Actinomycetales, Beggiatoa

III. Settling characteristics of the sludge

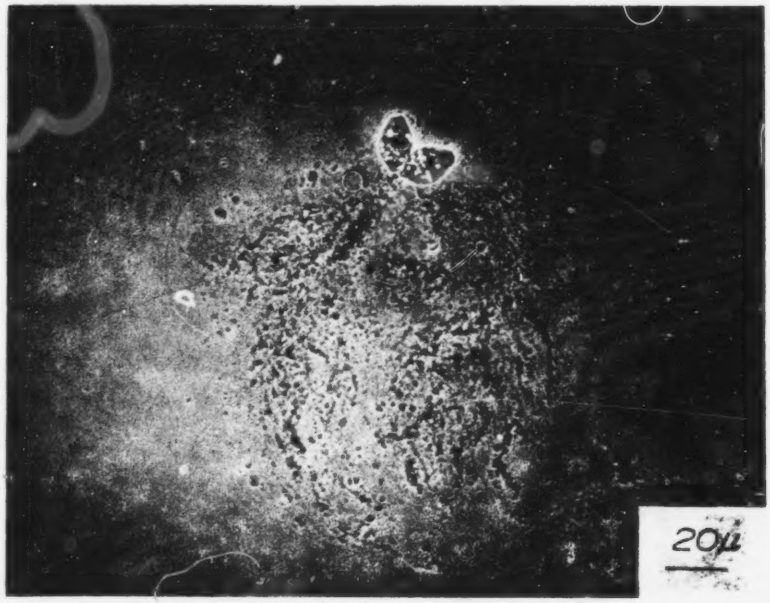
A. Settling rate (mls/minute) 285
B. Compaction rate (mls/minute) 0.45
C. Sludge Volume Index (mls/gm) 148

IV. Plant performance as indicated by:

A. Loading 0.299 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 46 mg/l
C. BOD reduction 64%

D. Type of waste - domestic and industrial (includes wash water from milk receiving plant)
E. Special problems - loss of solids from secondary clarifier

100μ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Plant Location Milton, Wisconsin, #42 Date January 4, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	$5{,}500\ \mu^2$	$25{,}000\ \mu^2$
C. Standard deviation	2.7	9.4
D. No. counted per ml.	139,000	977,000
E. No. counted per gm.	164,000	1,150,000

F. Types of protozoans - numerous stalked ciliates and flagellates; rare amoebas

G. Types of invertebrates - rare nematodes

H. Other observations - highly filamentous, medium to low density floc particles with lacey edges, medium amount of dispersed material and rare fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Arthrobacter, Brevibacterium

B. Present in small numbers - Actinomycetales, Sphaerotilus, Beggiatoa

III. Settling characteristics of the sludge

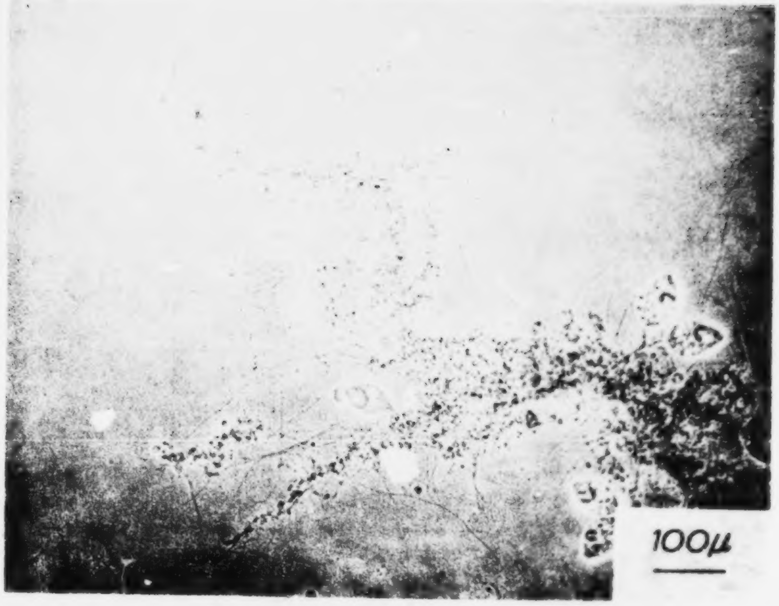
A. Settling rate (mls/minute) 176
B. Compaction rate (mls/minute) 0.67
C. Sludge Volume Index (mls/gm) 250

IV. Plant performance as indicated by:

A. Loading 0.799 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 30 mg/1
C. BOD reduction 91%

D. Type of waste - domestic and industrial

E. Special problems - very low solids in aeration tank due to loss of solids from secondary clarifier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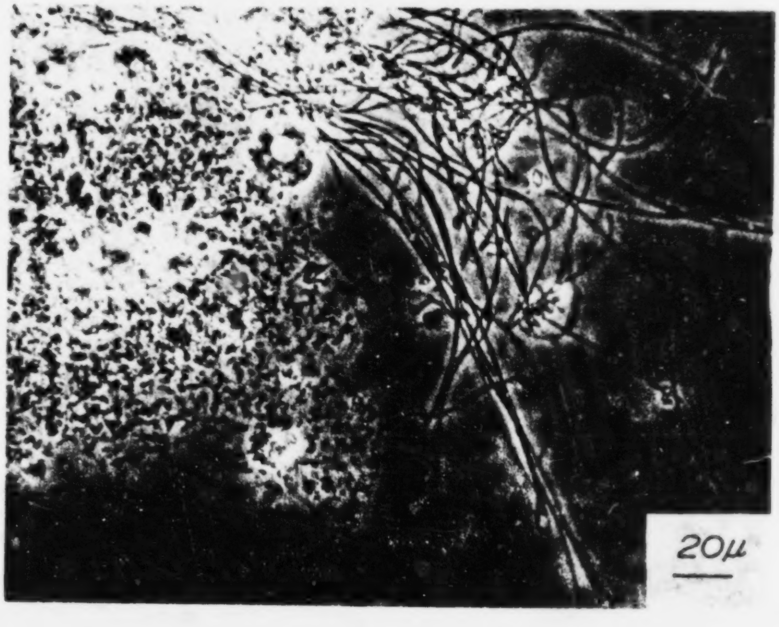
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Plant Location Milton, Wisconson, #60　　Date June 21, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	4,500 μ^2	10,900 μ^2
C. Standard deviation	3.0	2.6
D. No. counted per ml.	164,000	2,480,000
E. No. counted per gm.	315,000	4,770,000

F. Types of protozoans - numerous stalked ciliates and flagellates; rare amoebas

G. Types of invertebrates - none observed

H. Other observations - low density, highly filamentous floc particles of various sizes; medium concentration of dispersed material; rare fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Beggiatoa, Arthrobacter

B. Present in small numbers Bacillus, Actinomycetales

III. Settling characteristics of the sludge

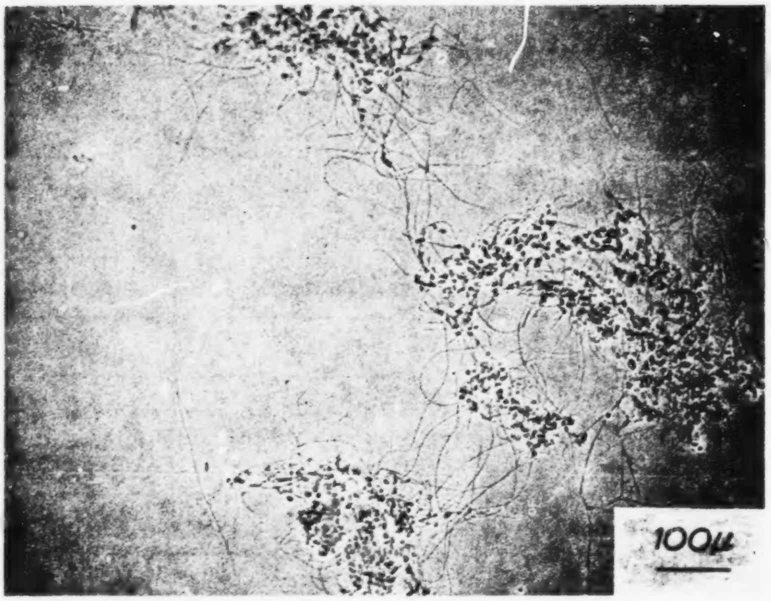
A. Settling rate (mls/minute) 48
B. Compaction rate (mls/minute) 1.95
C. Sludge Volume Index (mls/gm) 946

IV. Plant performance as indicated by:

A. Loading 0.518 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 14 mg/l
C. BOD reduction 90%

D. Type of waste - domestic and industrial

E. Special problems - very low solids in aeration tank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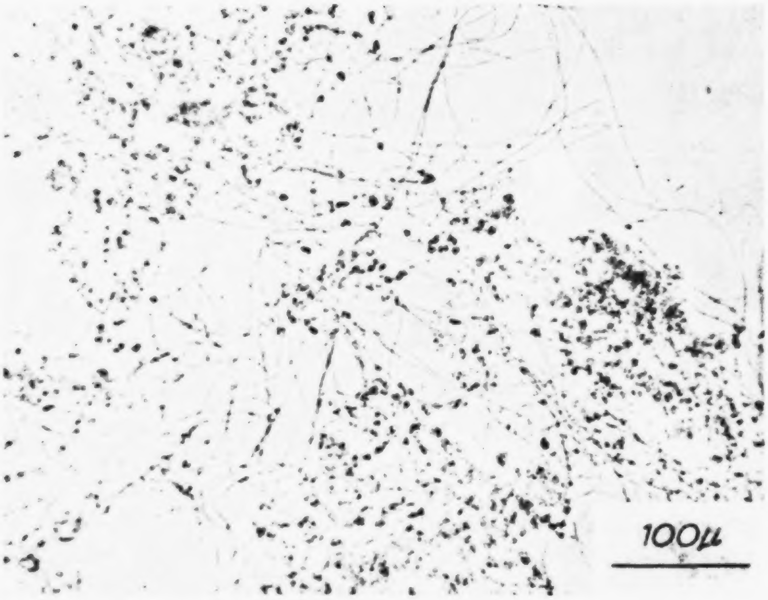
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Plant Location Brookfield, Wisconsin, #10 Date November 10, 1966

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	5,800 μ^2	13,000 μ^2
C. Standard deviation	2.8	2.6
D. No. counted per ml.	270,000	3,090,000
E. No. counted per gm.	293,000	3,360,000

F. Types of protozoans - rare stalked ciliates and free swimming ciliates; numerous flagellates

G. Types of invertebrates - numerous rotifers

H. Other observations - highly filamentous floc particles with low density; moderate dispersed material; rare spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Arthrobacter

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

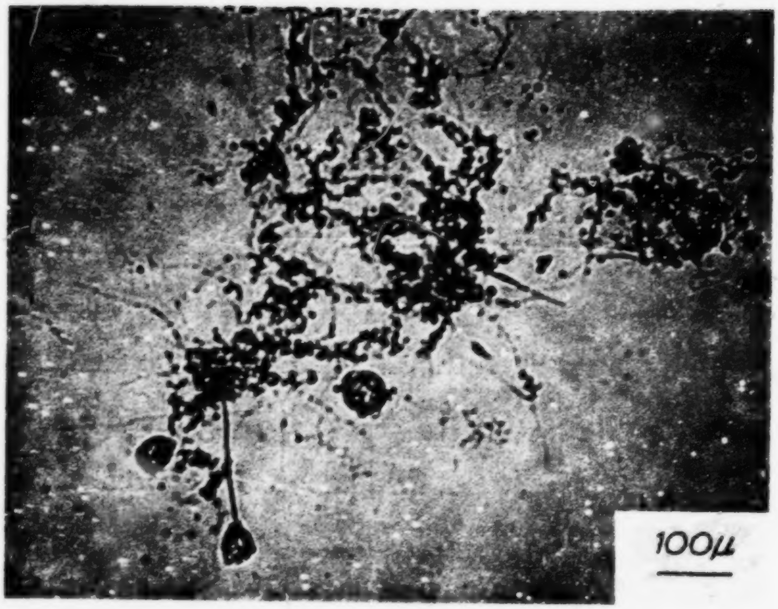
A. Settling rate (mls/minute) 29
B. Compaction rate (mls/minute) 2.1
C. Sludge Volume Index (mls/gm) 676

IV. Plant performance as indicated by:

A. Loading 0.185 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 12 mg/1
C. BOD reduction 80%

D. Type of waste - domestic

E. Special problems - chronic bulking during periods of low flow; loss of sludge particles during high flow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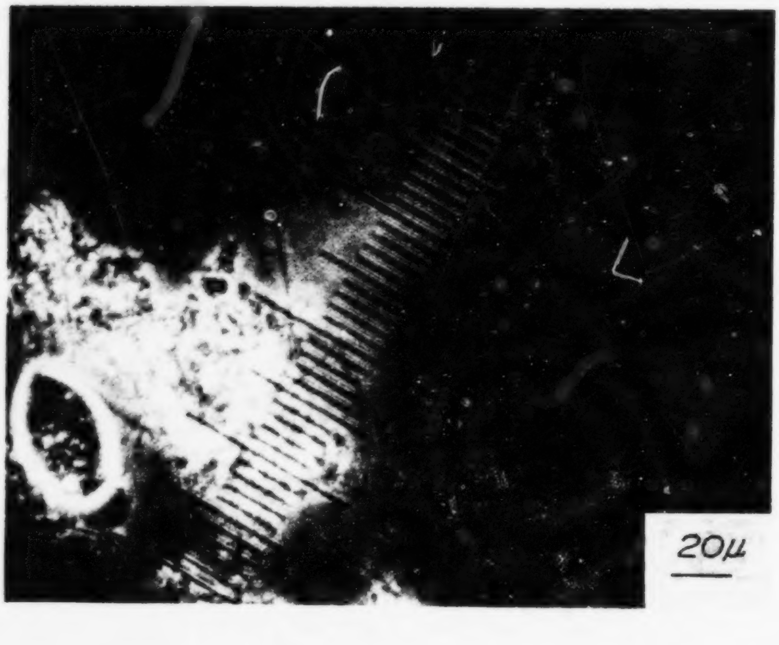
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Plant Location Brookfield, Wisconsin, #19 Date March 30, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	6,200 μ^2	16,000 μ^2
C. Standard deviation	2.7	2.3
D. No. counted per ml.	215,000	858,000
E. No. counted per gm.	181,000	720,000

F. Types of protozoans - numerous stalked ciliates and amoebas; rare free swimming ciliates

G. Types of invertebrates - numerous rotifers

H. Other observations - small to medium size highly filamentous floc particles of low to medium density; moderate concentration of dispersed material

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus

B. Present in small numbers - Actinomycetales, Sphaerotilus

III. Settling characteristics of the sludge

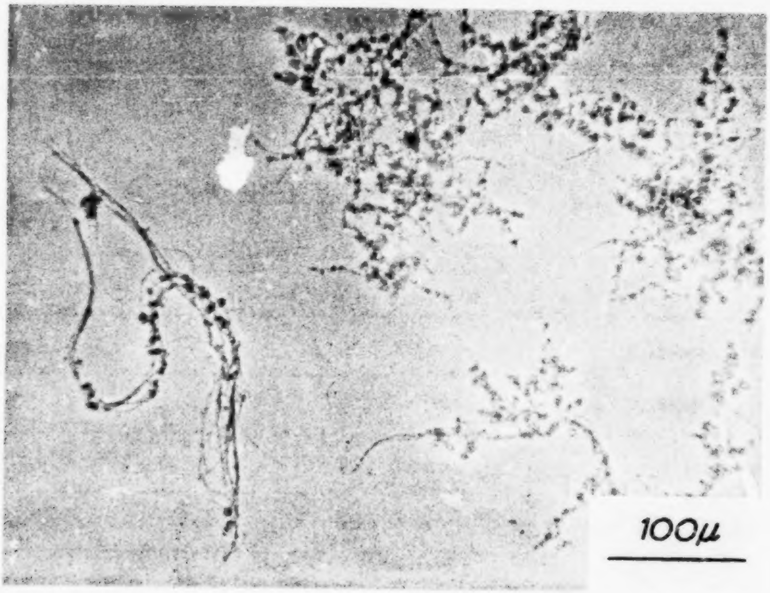
A. Settling rate (mls/minute) 285
B. Compaction rate (mls/minute) 0.49
C. Sludge Volume Index (mls/gm) 161

IV. Plant performance as indicated by:

A. Loading 0.114 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 21 mg/1
C. BOD reduction 55%

D. Type of waste - domestic

E. Special problems - chronic bulking during period of low flow; loss of sludge particles during high flow; rising sludge was obtained after one hour during settling tests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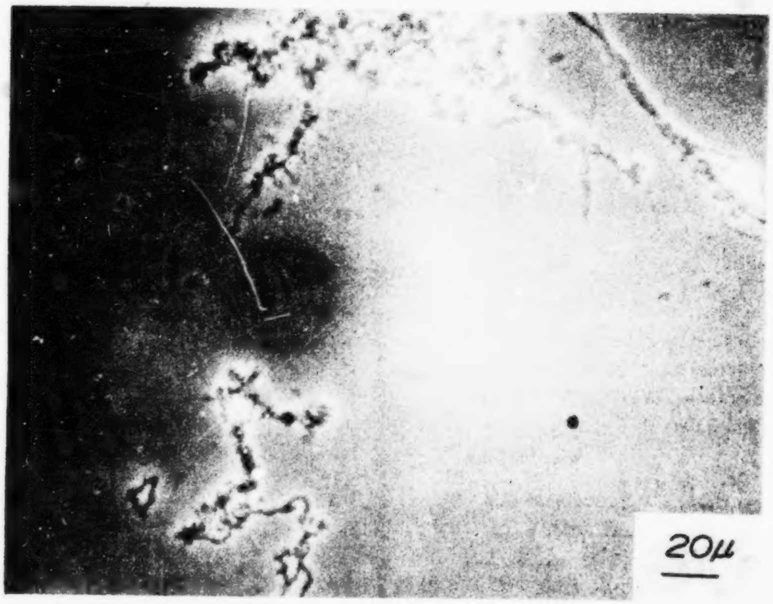
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Plant Location Brookfield, Wisconsin, #43

Date January 11, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	4,500 μ^2	13,400 μ^2
C. Standard deviation	3.1	2.9
D. No. counted per ml.	535,000	avg 5,100,000
E. No. counted per gm.	324,000	3,090,000

F. Types of protozoans - rare stalked ciliates and flagellates; numerous free swimming ciliates and amoebas

G. Types of invertebrates - numerous rotifers

H. Other observations - medium to low density floc particles of various sizes and with numerous filaments; moderate concentration of dispersed material

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Arthrobacter, Brevibacterium

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) rising sludge
B. Compaction rate (mls/minute) rising sludge
C. Sludge Volume Index (mls/gm) 548

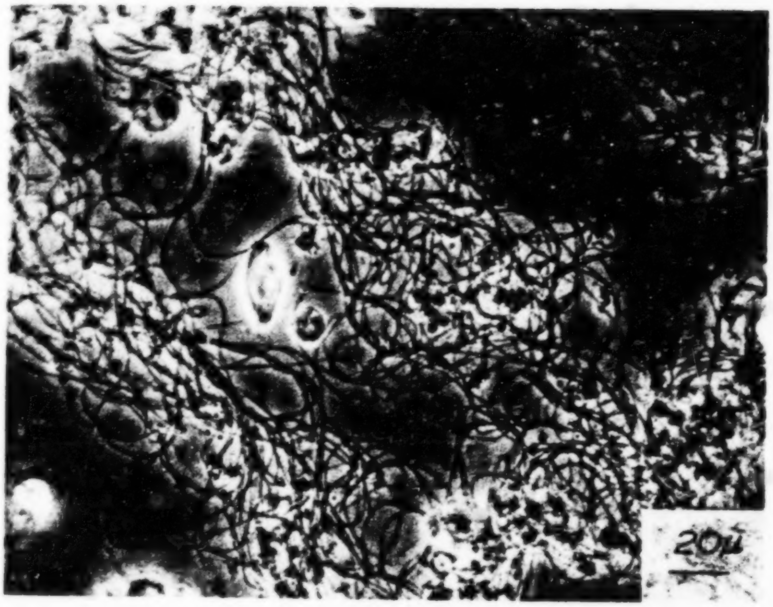
IV. Plant performance as indicated by:

A. Loading 0.317 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 44 mg/1
C. BOD reduction 76%

D. Type of waste - domestic

E. Special problems - chronic bulking during period of low flow; loss of sludge particles during high flow; rising sludge was obtained after one-half hour during settling tests in laboratory

100μ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Plant Location Brookfield, Wisconsin, #61 Date July 11, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	5,100 μ^2	11,300 μ^2
C. Standard deviation	2.58	2.45
D. No. counted per ml.	530,000	2,410,000
E. No. counted per gm.	308,000	1,400,000

F. Types of protozoans - numerous stalked ciliates, flagellates, amoebas, and free swimming ciliates

G. Types of invertebrates - rare rotifers and nematodes

H. Other observations - low to medium density floc with numerous filaments; medium concentration of dispersed material; rare fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Sphaerotilus

B. Present in small numbers - Bacillus, Actinomycetales, Arthrobacter

III. Settling characteristics of the sludge

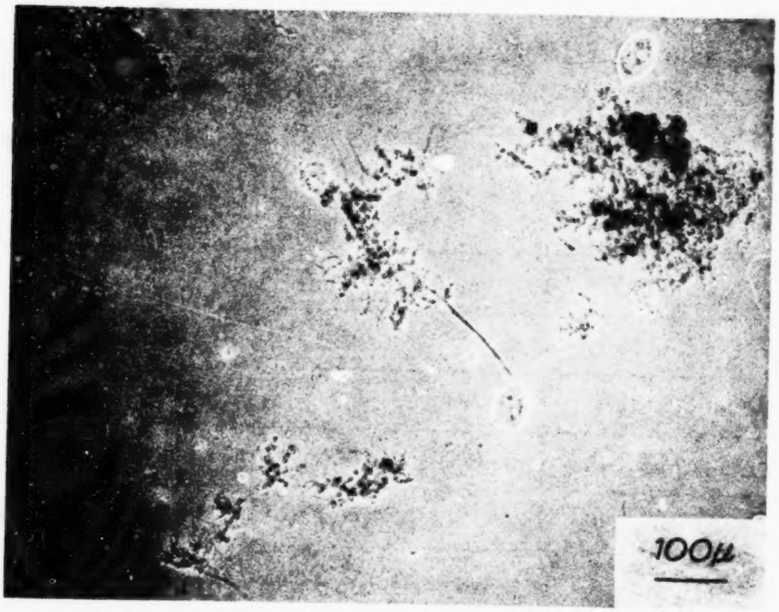
A. Settling rate (mls/minute) 225
B. Compaction rate (mls/minute) 0.6
C. Sludge Volume Index (mls/gm) 100

IV. Plant performance as indicated by:

A. Loading 0.090 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 48.7 mg/1
C. BOD reduction 9%

D. Type of waste - domestic

E. Special problems - chronic bulking during period of low flow; loss of sludge particles during high flow; a recent rainfall along with an inoperable grit chamber and poor process efficiency are some of the most recent problems in this plant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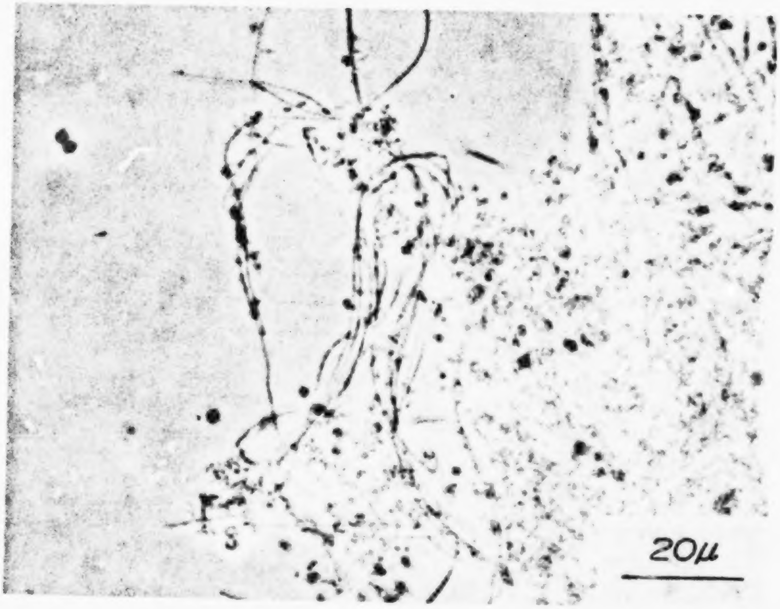
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Plant Location Woodstock, Illinois, #11   Date November 17, 1966

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	--
B. Geometric mean	--	--
C. Standard deviation	--	--
D. No. counted per ml.	100 7,100,000	673,000
E. No. counted per gm.	2,060,000	190,000

F. Types of protozoans - numerous stalked ciliates, flagellates, and amoebas; numerous free swimming ciliates

G. Types of invertebrates - numerous rotifers, various species

H. Other observations - floc particles are very small with a high concentration of Actinomycetales. The concentration of dispersed material was only moderate; a few fungal filaments observed

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - None

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

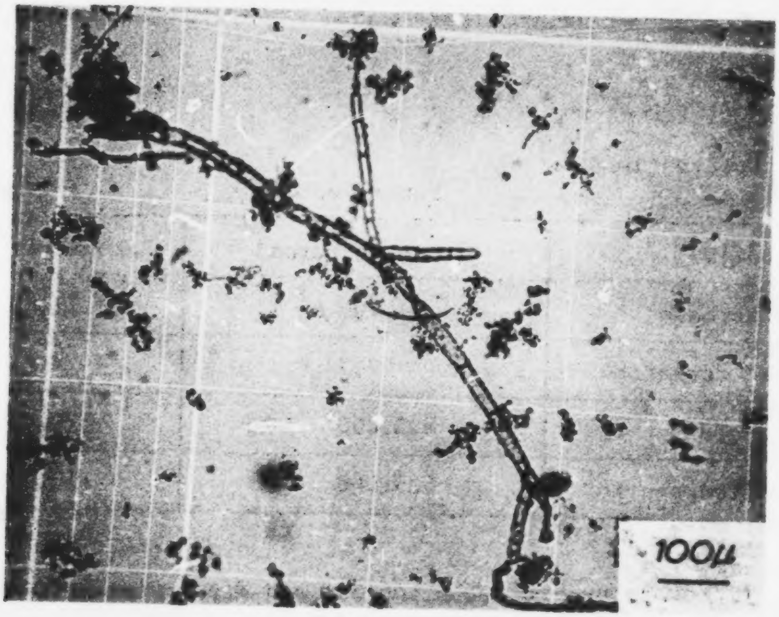
A. Settling rate (mls/minute) 80
B. Compaction rate (mls/minute) 0.64
C. Sludge Volume Index (mls/gm) 38

IV. Plant performance as indicated by:

A. Loading 0.015 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 11 mg/1
C. BOD reduction 87%

D. Type of waste - domestic and industrial (includes dairy and plating wastes, rug cleaning, tool and die manufacture)

E. Special problems - no dairy waste received with this sample although plant does receive periodic discharge of waste solids from dairy waste activated sludge treatment plant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Plant Location Woodstock, Illinois, #25 Date June 27, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	1,700 μ^2	4,000 μ^2
C. Standard deviation	2.7	2.4
D. No. counted per ml.	805,000	170,000
E. No. counted per gm.	509,000	110,000

F. Types of protozoans - numerous amoebas and free swimming ciliates; rare stalked ciliates and flagellates

G. Types of invertebrates - numerous rotifers

H. Other observations - small, medium density floc particles with much insect debris, many Actinomycetales, moderate concentration of dispersed material; rare fungal filaments and zoogleal formation

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Actinomycetales, Sphaerotilus

B. Present in small numbers -- None

III. Settling characteristics of the sludge

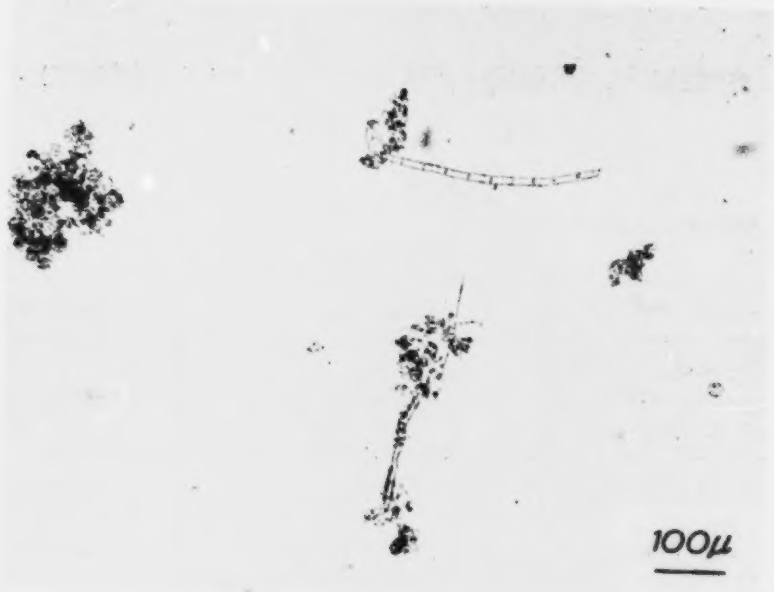
A. Settling rate (mls/minute) 450
B. Compaction rate (mls/minute) 0.01
C. Sludge Volume Index (mls/gm) 50

IV. Plant performance as indicated by:

A. Loading $0.021 \ \frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 22 mg/l
C. BOD reduction 59%

D. Type of waste - domestic and industrial (includes dairy and plating wastes, rug cleaning, tool and die manufacture)

E. Special problems - plant receives periodic discharge of waste solids from dairy waste, activated sludge treatment plant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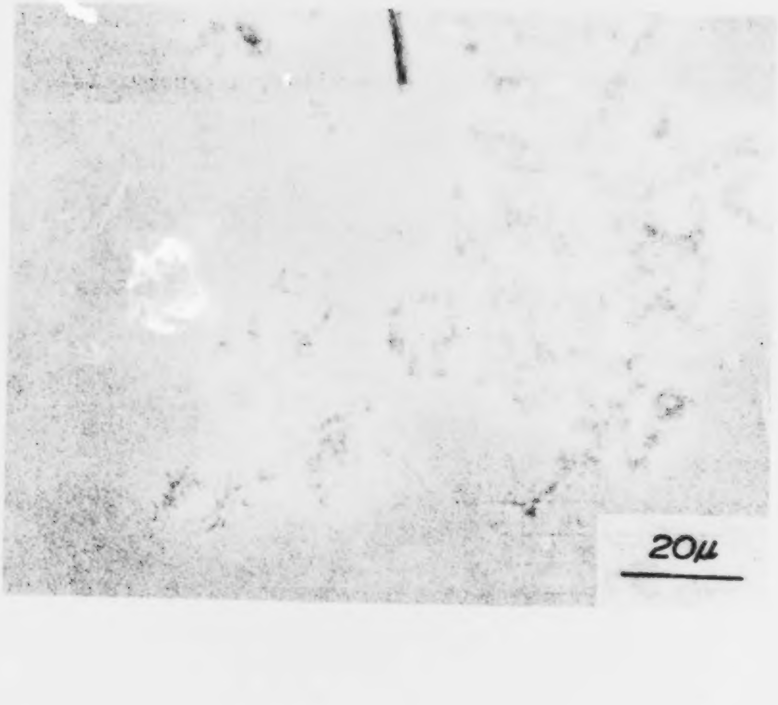
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Plant Location Woodstock, Illinois, #47 Date February 8, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	nongeometric	nongeometric
B. Geometric mean	--	--
C. Standard deviation	--	--
D. No. counted per ml.	5,950,000	1,830,000
E. No. counted per gm.	1,930,000	590,000

F. Types of protozoans -- rare stalked ciliates, flagellates, and amoebas

G. Types of invertebrates - rare rotifers

H. Other observations - small compact floc particles with many filaments and small colonies of Actinomycetales; medium concentration of dispersed material; rare fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Actinomycetales, Sphaerotilus

B. Present in small numbers - - None

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 180
B. Compaction rate (mls/minute) 0.59
C. Sludge Volume Index (mls/gm) 65

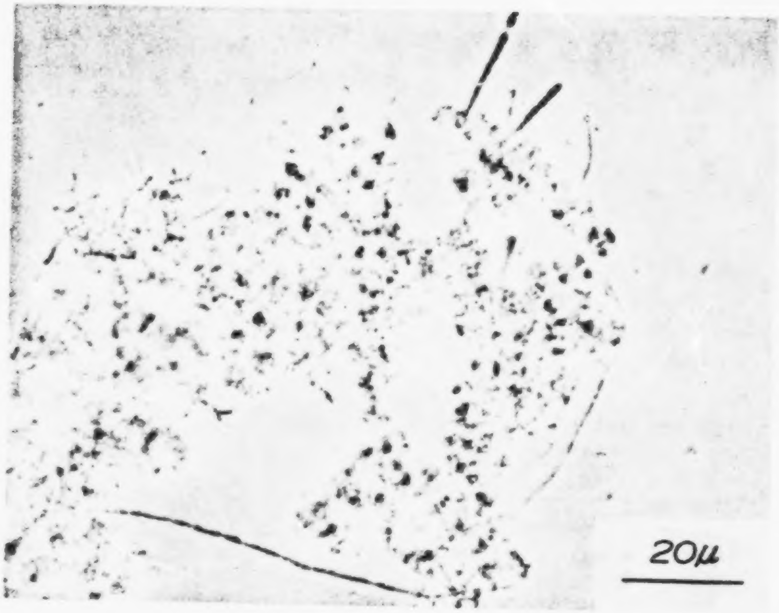
IV. Plant performance as indicated by:

A. Loading 0.018 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 28 mg/1
C. BOD reduction 69%

D. Type of waste - domestic and industrial (includes dairy and plating waste, rug cleaning, tool and die manufacture)

E. Special problems - plant receives periodic discharge of waste solids from dairy waste, activated sludge plant

100μ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Plant Location **Woodstock, Illinois, #51** Date **March 21, 1968**

I. Microscopic Observations

		Particles	Filaments
A.	Distribution	geometric normal	--
B.	Geometric mean	1,650 μ^2	--
C.	Standard deviation	2.2	--
D.	No. counted per ml.	3,820,000	442,000
E.	No. counted per gm.	1,270,000	140,000

F. Types of protozoans - numerous stalked ciliates; rare amoebas and free swimming ciliates

G. Types of invertebrates - numerous rotifers; rare nematodes

H. Other observations - numerous small floc particles of medium density and small filamentous Actinomycetales; moderate concentration of dispersed material; few fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Actinomycetales, Sphaerotilus, Arthrobacter

B. Present in small numbers - None

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 145
B. Compaction rate (mls/minute) 0.44
C. Sludge Volume Index (mls/gm) 67

IV. Plant performance as indicated by:

A. Loading 0.019 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 20 mg/1
C. BOD reduction 79%

D. Type of waste - domestic and industrial (includes dairy and plating wastes, rug cleaning, tool and die manufacture)

E. Special problems - plant receives periodic discharge of waste solids from dairy waste, activated sludge plant

100μ

20μ

Plant Location **Gages Lake, Illinois, #12**   Date **December 15, 1966**

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	6,700 μ^2	9,680 μ^2
C. Standard deviation	2.1	2.1
D. No. counted per ml.	615,000	3,010,000
E. No. counted per gm.	152,000	747,000

F. Types of protozoans - numerous stalked ciliates, flagellates, amoebas, and free swimming ciliates

G. Types of invertebrates - numerous rotifers, various species

H. Other observations medium to low density floc particles with numerous small filaments including colonies of Actinomycetales, moderate concentration of dispersed material, rare fungus, few spirochaetes, a few zoogleal colonies

II. Filamentous organisms isolated from sludge

A. Present in significant numbers -- Actinomycetales

B. Present in small numbers --Bacillus

III. Settling characteristics of the sludge

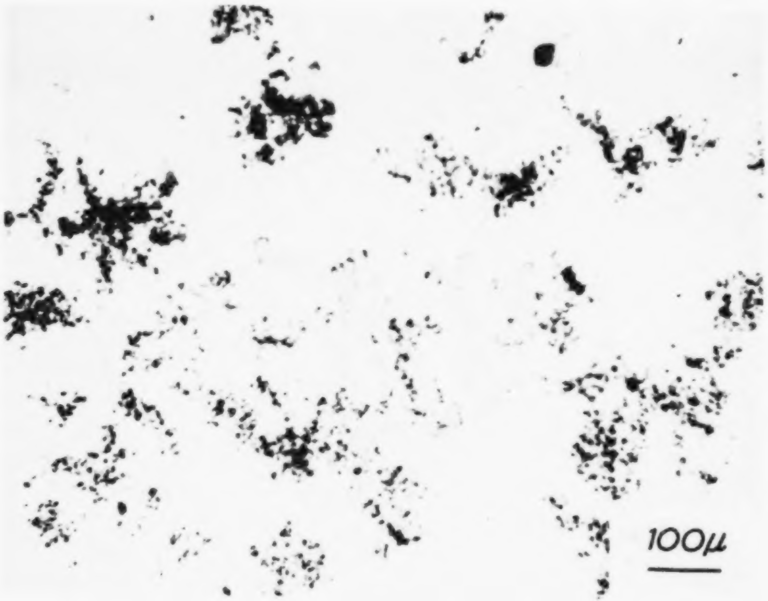
A. Settling rate (mls/minute) -
B. Compaction rate (mls/minute) 3.5
C. Sludge Volume Index (mls/gm) 189

IV. Plant performance as indicated by:

A. Loading 0.043 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 10 mg/l
C. BOD reduction 95%

D. Type of waste - domestic

E. Special problems - periodic problems with rising and floating sludge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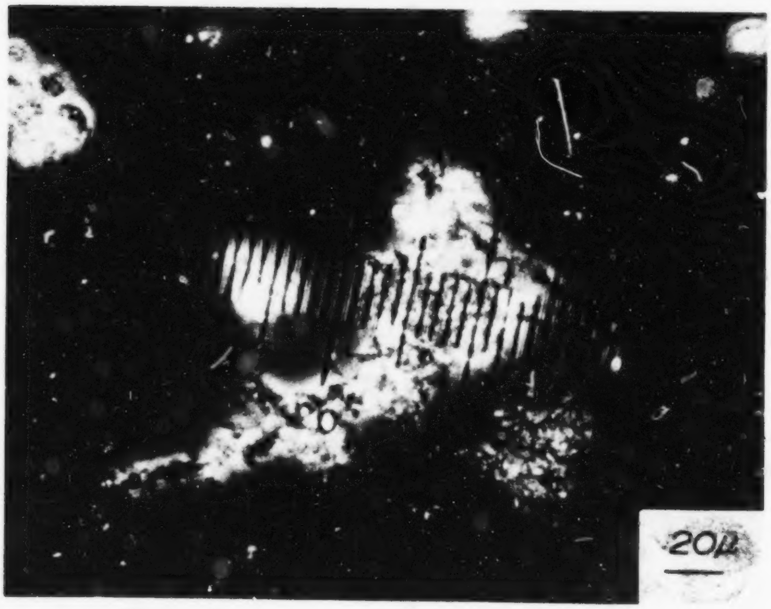
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Plant Location Gages Lake, Illinois, #27 Date July 18, 1967

I. Microscopic Observations

		Particles	Filaments
A.	Distribution	geometric normal	geometric normal
B.	Geometric mean	5,500 μ^2	11,000 μ^2
C.	Standard deviation	2.6	2.2
D.	No. counted per ml.	788,000	2,570,000
E.	No. counted per gm.	166,000	540,000

F. Types of protozoans - numerous stalked ciliates, flagellates and amoebas; rare free swimming ciliate

G. Types of invertebrates - numerous rotifers

H. Other observations - medium to low density floc particles with many small filaments; moderate concentration of dispersed material

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Actinomycetales

B. Present in small numbers - Bacillus

III. Settling characteristics of the sludge

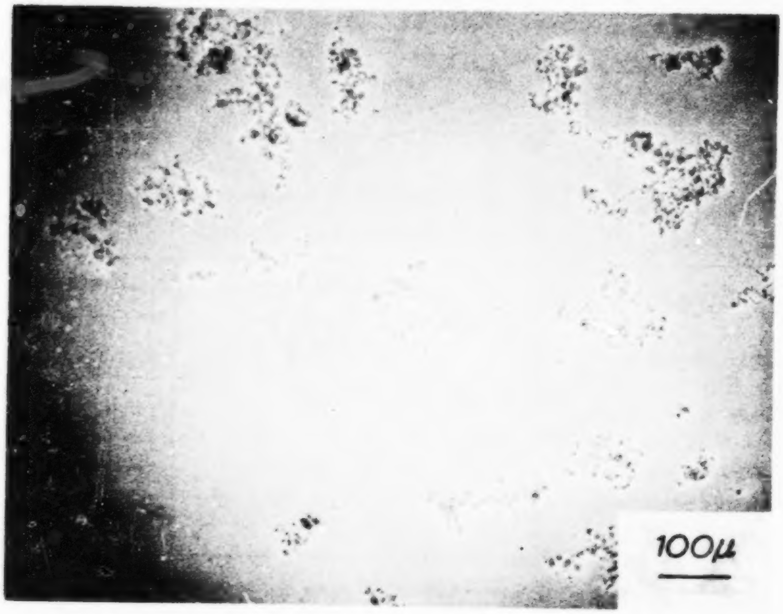
A. Settling rate (mls/minute) 9
B. Compaction rate (mls/minute) 2.30
C. Sludge Volume Index (mls/gm) 146

IV. Plant performance as indicated by:

A. Loading 0.043 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 10 mg/1
C. BOD reduction 95%

D. Type of waste- domestic

E. Special problems - periodic problems with rising and floating sludge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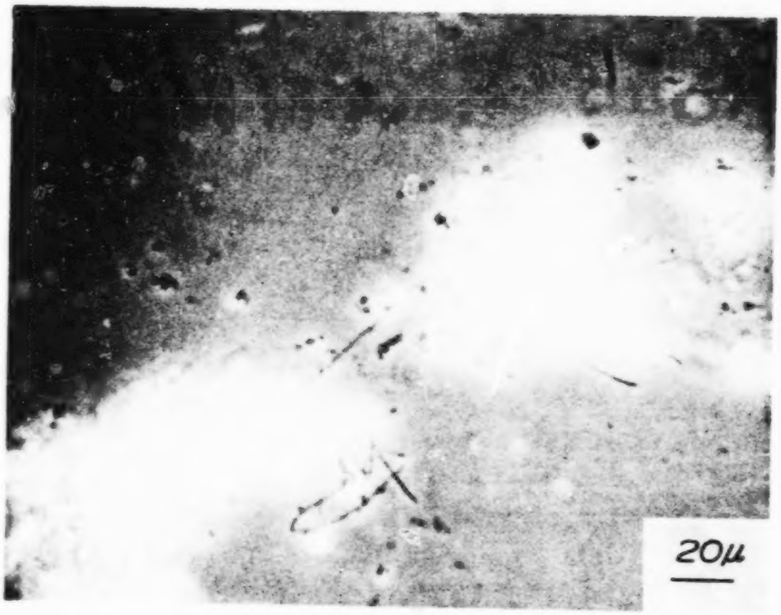
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Plant Location Gages Lake, Illinois, #45 Date January 25, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	$5,300\ \mu^2$	$11,100\ \mu^2$
C. Standard deviation	2.2	2.3
D. No. counted per ml.	1,440,000	9,020,000
E. No. counted per gm.	358,000	2,240,000

F. Types of protozoans - numerous stalked ciliates, flagellates, and free swimming ciliates; rare amoebas

G. Types of invertebrates - none observed

H. Other observations -medium to low density floc particles of various sizes and with numerous filaments; medium concentration of dispersed material; few spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Arthrobacter

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

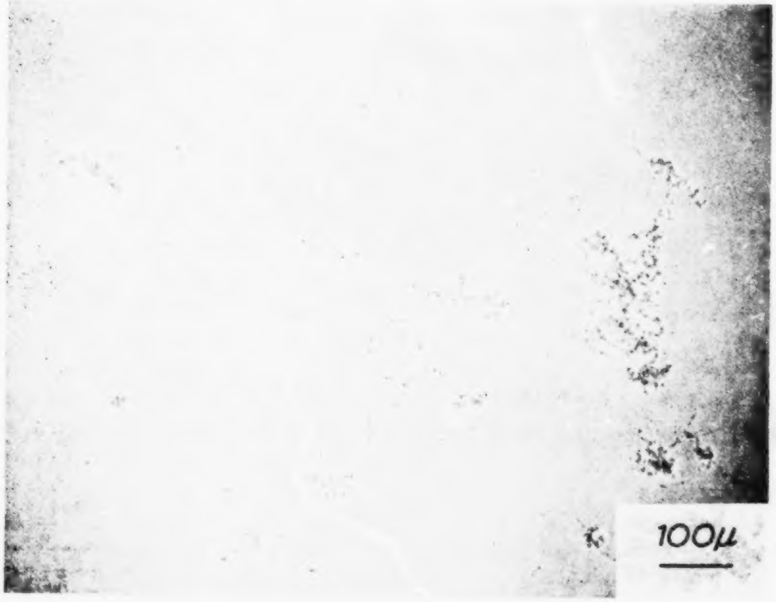
A. Settling rate (mls/minute) 5
B. Compaction rate (mls/minute)
C. Sludge Volume Index (mls/gm) 245

IV. Plant performance as indicated by:

A. Loading $0.047\ \frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 24 mg/l
C. BOD reduction 87%

D. Type of waste - domestic

E. Special problems - periodic problems with rising and floating sludge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Plant Location Gages Lake, Illinois, #52 Date March 28, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	nongeometric	nongeometric
B. Geometric mean	5,170 μ^2	9,620 μ^2
C. Standard deviation	2.2	2.5
D. No. counted per ml.	941,000	2,460,000
E. No. counted per gm.	324,000	850,000

F. Types of protozoans - numerous stalked ciliates, amoebas, and free swimming ciliates; rare flagellates

G. Types of invertebrates - numerous rotifers

H. Other observations - medium density floc particles of various sizes and with numerous small to medium filaments; rare fungal filaments and spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Actinomycetales

B. Present in small numbers - None

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 64
B. Compaction rate (mls/minute) 1.10
C. Sludge Volume Index (mls/gm) 120

IV. Plant performance as indicated by:

A. Loading 0.103 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 15 mg/1
C. BOD reduction 95%

D. Type of waste - domestic

E. Special problems - periodic problems with rising and floating sludge

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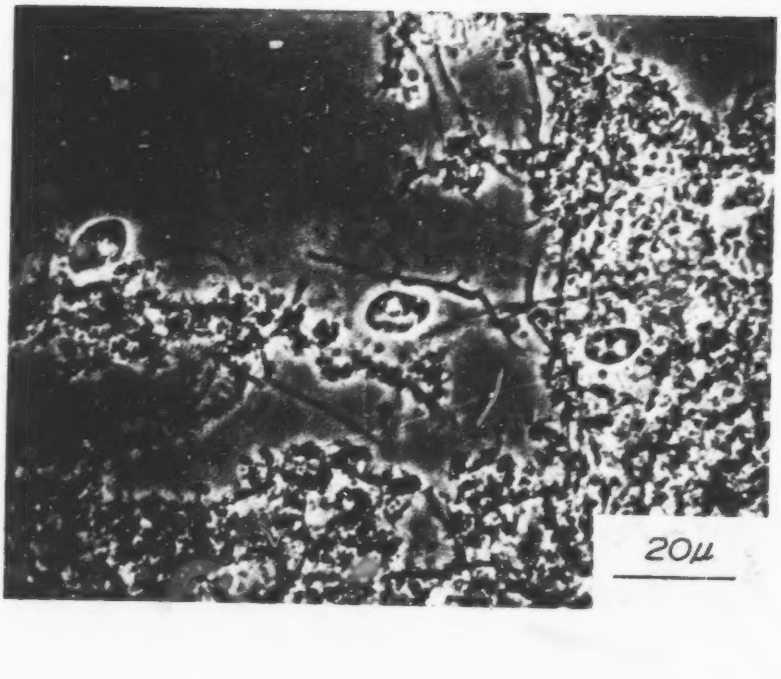
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Plant Location Libertyville, Illinois, #13 Date December 22, 1966

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	3,800 μ^2	13,000 μ^2
C. Standard deviation	2.7	3.0
D. No. counted per ml.	641,000	5,600
E. No. counted per gm.	284,000	2,500

F. Types of protozoans - numerous stalked ciliates, flagellates, amoebas and free swimming ciliates

G. Types of invertebrates - none observed

H. Other observations - compact floc particles with slight tendency to disperse; medium concentration of dispersed material, spirochaetes

II. Filamentous organisms isolated from sludge rarely seen

A. Present in significant numbers - None

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 520

B. Compaction rate (mls/minute) 0.35

C. Sludge Volume Index (mls/gm) 51%

IV. Plant performance as indicated by:

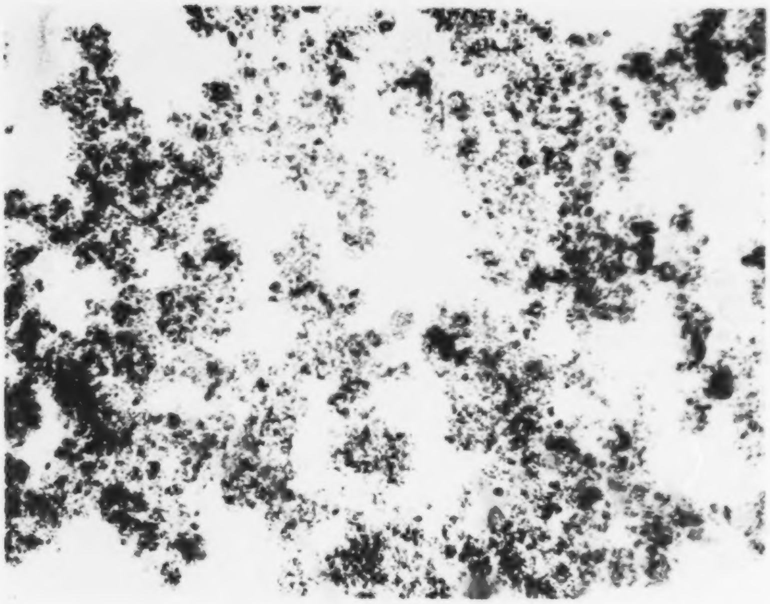
A. Loading $0.172 \ \frac{\text{lbs BOD/day}}{\text{lb MLSS}}$

B. Effluent BOD 11 mg/l

C. BOD reduction 88%

D. Type of waste - domestic and industrial (metal plating, machine manufacture, macaroni factory, and research laboratory)

E. Special problems - this is a new plant



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Plant Location Libertyville, Illinois, #24 Date June 20, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	2,800 μ^2	6,500 μ^2
C. Standard deviation	3.1	3.5
D. No. counted per ml.	555,000	19,000
E. No. counted per gm.	171,000	10,000

F. Types of protozoans - numerous stalked ciliates, flagellates, amoebas, rare free swimming ciliates

G. Types of invertebrates - numerous rotifers; rare nematodes

H. Other observations - small, compact floc particles with rare filaments; moderate concentrations of dispersed material; zoogleal formation rarely seen

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus

B. Present in small numbers - Actinomycetales

III. Settling characteristics of the sludge

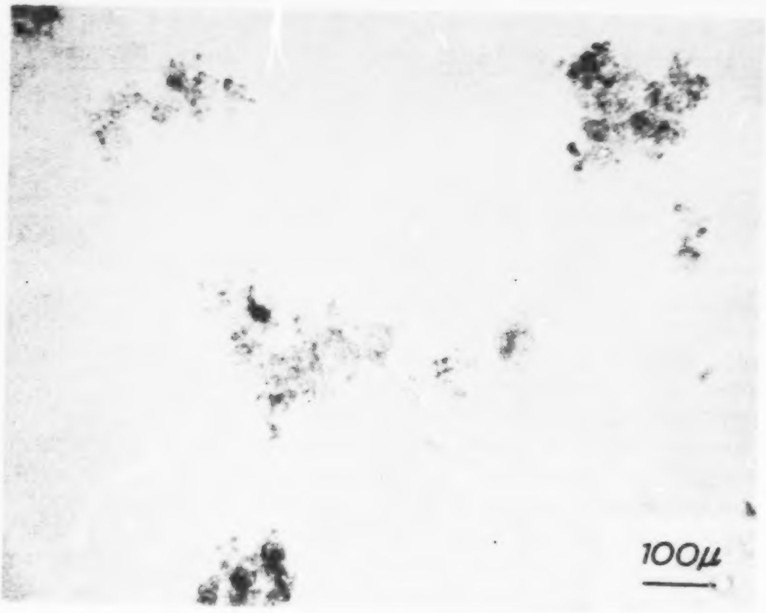
A. Settling rate (mls/minute) 280
B. Compaction rate (mls/minute) 0.17
C. Sludge Volume Index (mls/gm) 38%

IV. Plant performance as indicated by:

A. Loading 0.048 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 9 mg/1
C. BOD reduction 76%

D. Type of waste - domestic and industrial (metal plating, machine manufacture, macaroni manufacture, and research laboratory)

E. Special problems - the plant was experiencing high flow due to rain and infiltration; sludge was being lost because of billowing and pin point floc in the secondary clarifier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Plant Location Libertyville, Illinois, #40 Date November 30, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	7,200 μ^2	10,600 μ^2
C. Standard deviation	2.1	1.9
D. No. counted per ml.	186,000	71,000
E. No. counted per gm.	162,000	60,000

F. Types of protozoans - rare stalked ciliates; flagellates, amoebas; numerous free swimming ciliates

G. Types of invertebrates - none observed

H. Other observations - compact but ragged floc particles of various sizes; medium amount of dispersed material; rare fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - none

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 103
B. Compaction rate (mls/minute) 0.21
C. Sludge Volume Index (mls/gm) 82

IV. Plant performance as indicated by:

A. Loading 0.281 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 17 mg/l
C. BOD reduction 78%

D. Type of waste - domestic and industrial (metal plating, machine manufacture, macaroni manufacture, and research laboratory)

E. Special problems - occasional loss of pin point floc and occurrence of billowing sludge in secondary clarifier

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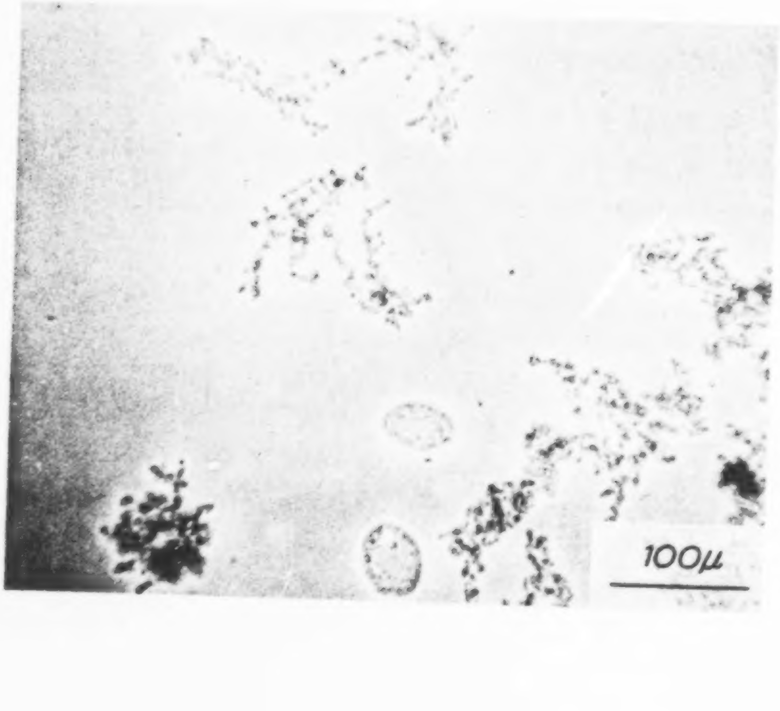
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Plant Location Libertyville, Illinois, #62 Date July 18, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	2,100 μ^2	7,000 μ^2
C. Standard deviation	3.41	2.88
D. No. counted per ml.	785,000	195,000
E. No. counted per gm.	408,000	101,000

F. Types of protozoans - numerous flagellates; rare stalked ciliates and amoebas

G. Types of invertebrates - rare rotifers

H. Other observations - small compact floc particles with few filaments; moderate concentration of dispersed material; few fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus

B. Present in small numbers - Actinomycetales

III. Settling characteristics of the sludge

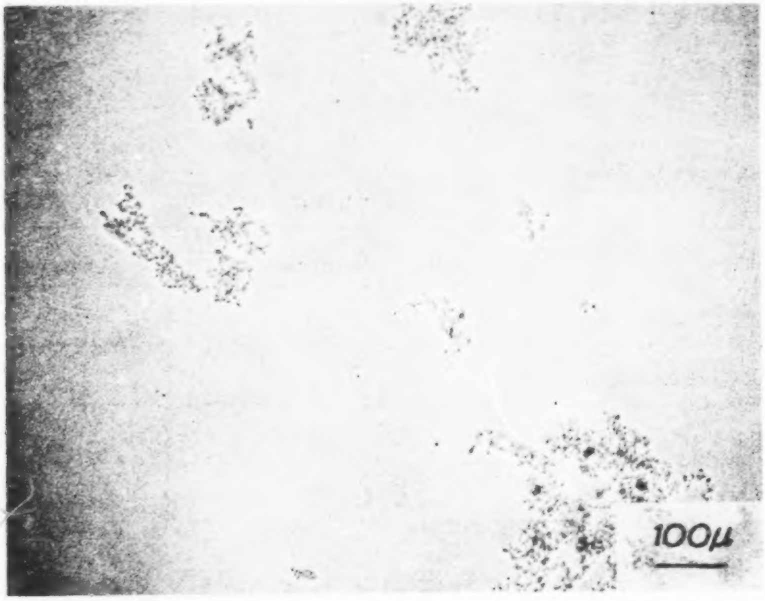
A. Settling rate (mls/minute) 520
B. Compaction rate (mls/minute) 0.147
C. Sludge Volume Index (mls/gm) 4[illegible]

IV. Plant performance as indicated by:

A. Loading 0.054 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 23.4 mg/1
C. BOD reduction 47%

D. Type of waste - domestic and industrial (metal plating, machine manufacture, macaroni factory, and research laboratory)

E. Special problems - a change from conventional process to contact stabilization was started about 3-4 months previous to this date. Very little increase in plant efficiency was obtained and sludge solids are continually lost due in part to a billowing problem in the secondary clarifier. Return sludge solids have not been kept much more than two times the mixed liquor suspended solids. About 0.8 inches of rain fell on the night previous to taking this sample.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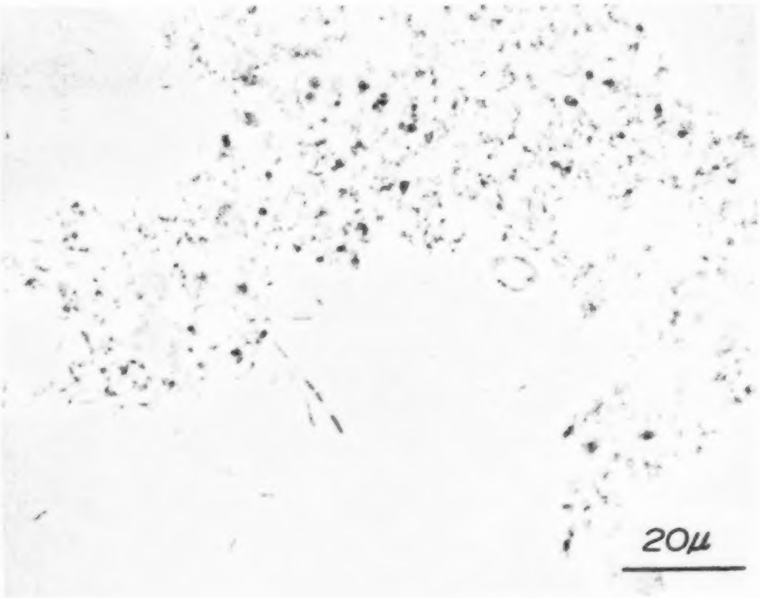
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Plant Location Spinney Run, Illinois, #14

Date January 5, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	$660\ \mu^2$	$22{,}000\ \mu^2$
C. Standard deviation	9.4	2.7
D. No. counted per ml.	487,000	76,000
E. No. counted per gm.	497,000	610,000

F. Types of protozoans -numerous flagellates

G. Types of invertebrates - none observed

H. Other observations - many small floc particles as well as larger, filamentous floc; the bacteria appear to dominate the floc and are heavily concentrated in the dispersed material

II. Filamentous organisms isolated from sludge

A. Present in significant numbers- Bacillus

B. Present in small numbers- Actinomycetales, Sphaerotilus

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 352
B. Compaction rate (mls/minute) 0.77
C. Sludge Volume Index (mls/gm) 163

IV. Plant performance as indicated by:

A. Loading 0.231 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 632 mg/1
C. BOD reduction -56%

D. Type of waste - milk waste from dairy

E. Special problems - almost continuous loss of sludge in secondary clarifier

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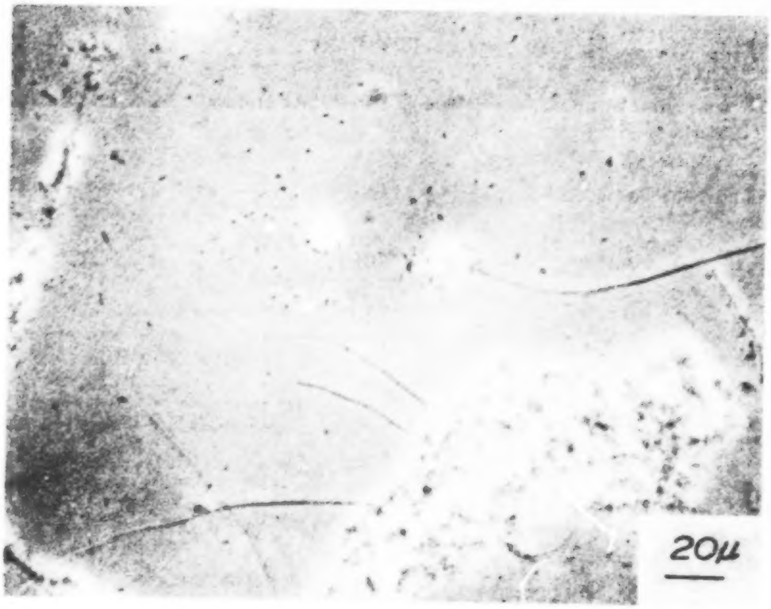
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Plant Location Spinney Run, Illinois, #20 Date April 13, 1967

1. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	2,900 μ^2	8,100 μ^2
C. Standard deviation	3.6	3.3
D. No. counted per ml.	281,000	704,000
E. No. counted per gm.	225,000	560,000

F. Types of protozoans - numerous stalked ciliates and flagellates

G. Types of invertebrates - none observed

H. Other observations - small to medium size floc particles with few filaments; moderate concentration of dispersed material and rare colonies showing zoogleal formation

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - none

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

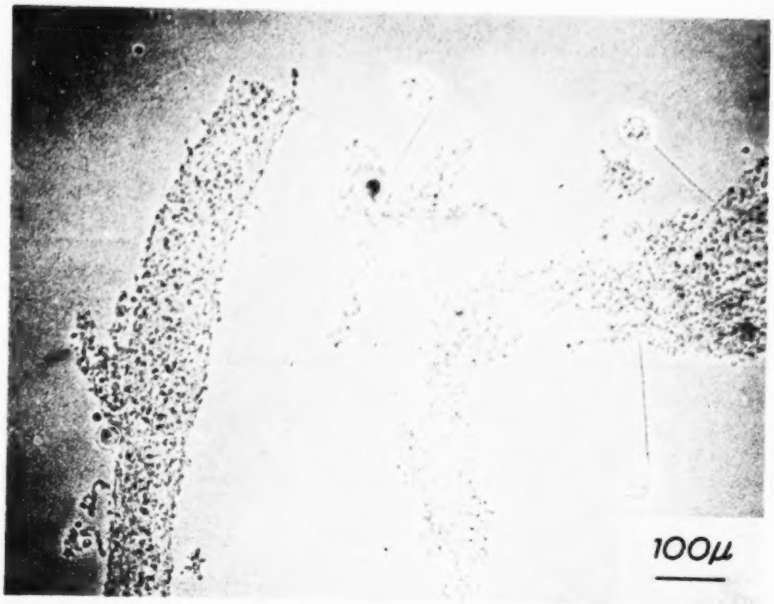
A. Settling rate (mls/minute) 370
B. Compaction rate (mls/minute) 0.32
C. Sludge Volume Index (mls/gm) 59

IV. Plant performance as indicated by:

A. Loading 0.290 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 19 mg/l
C. BOD reduction 97%

D. Type of waste - milk waste from dairy

E. Special problems - almost continuous loss of sludge in secondary clarifier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Plant Location Spinney Run, Illinois, #31 Date August 15, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	4,900 μ^2	10,600 μ^2
C. Standard deviation	2.6	2.8
D. No. counted per ml.	57,000	996,000
E. No. counted per gm.	150,000	2,630,000

F. Types of protozoans - numerous stalked ciliates, flagellates, and free swimming ciliates; rare amoebas

G. Types of invertebrates - none observed

H. Other observations - very filamentous, medium density floc with lacey edges; medium to small size range; medium concentration of dispersed material; rare spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Sphaerotilus, Arthrobacter, Brevibacterium

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) --
B. Compaction rate (mls/minute) 0.53
C. Sludge Volume Index (mls/gm) 263

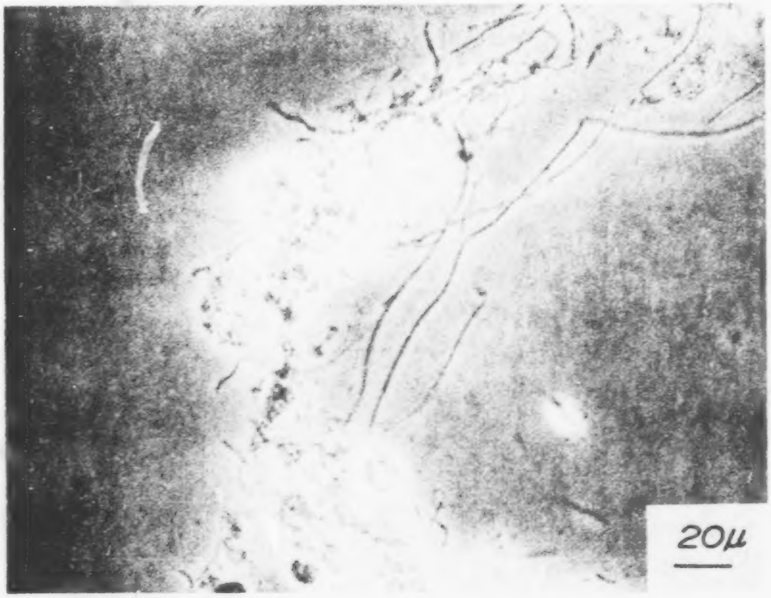
IV. Plant performance as indicated by:

A. Loading 0.426 $\frac{\text{lbs BOD/day}}{\text{lb MLSS.}}$
B. Effluent BOD 241 mg/l
C. BOD reduction 17%

D. Type of waste - milk waste from dairy

E. Special problems - very low solids in aeration tank; high solids in effluent

100μ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Plant Location Spinney Run, Illinois, #37 Date October 26, 1967

I. Microscopic Observations

		Particles	Filaments
A.	Distribution	nongeometric	nongeometric
B.	Geometric mean	5,600 μ^2	17,300 μ^2
C.	Standard deviation	2.8	3.2
D.	No. counted per ml.	29,000	89,000
E.	No. counted per gm.	85,000	260,000

F. Types of protozoans - numerous stalked ciliates, flagellates, amoebas, and free swimming ciliates

G. Types of invertebrates - none observed

H. Other observations - medium density floc particles with lacey edges and many filamentas; medium concentration of dispersed material; rare spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Sphaerotilus, Beggiatoa, Brevibacterium

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

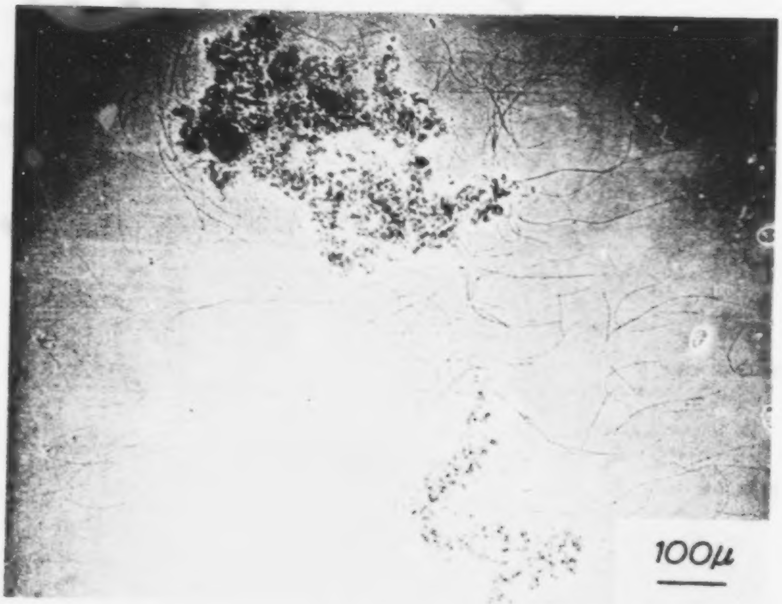
A. Settling rate (mls/minute) --
B. Compaction rate (mls/minute) --
C. Sludge Volume Index (mls/gm) 36

IV. Plant performance as indicated by:

A. Loading 1.100 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 369 mg/l
C. BOD reduction 45%

D. Type of waste - milk waste from dairy

E. Special problems - very low solids in aeration tank; high solids in effluent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Plant Location Borden's Dairy, #15
Woodstock, Illinois

Date January 19, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	$1,600\ \mu^2$	$2,900\ \mu^2$
C. Standard deviation	2.1	2.0
D. No. counted per ml.	1,870,000	2,680,000
E. No. counted per gm.	886,000	1,270,000

F. Types of protozoans - rare stalked ciliates; numerous flagellates

G. Types of invertebrates - none observed

H. Other observations- medium density floc particles with numerous small filaments including many colonies of Actinomycetales, medium concentration of dispersed material

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Actinomycetales

B. Present in small numbers - Bacillus, Sphaerotilus

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 67
B. Compaction rate (mls/minute) 0.67
C. Sludge Volume Index (mls/gm) 115

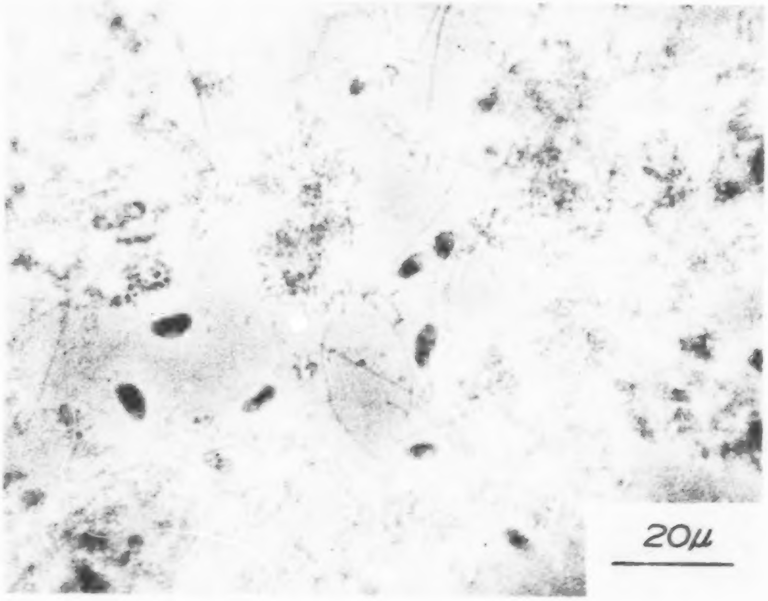
IV. Plant performance as indicated by:

A. Loading 0.053 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 292 mg/l
C. BOD reduction -101%

D. Type of waste - entirely from the manufacture of various dairy products

E. Special problems - loss of solids in effluent and production of foam in aeration tank

100μ



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Plant Location Borden's Dairy, #32
Woodstock, Illinois

Date August 22, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	--	--
B. Geometric mean	--	--
C. Standard deviation	--	--
D. No. counted per ml.	7,820,000	23,$\overset{400}{000}$,000
E. No. counted per gm.	1,640,000	4,910,000

F. Types of protozoans - numerous flagellates

G. Types of invertebrates - none observed

H. Other observations - many very small floc particles of medium density and with numerous small filaments (including Actinomycetales); many dispersed colonies of Actinomycetales

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Actinomycetales

B. Present in small numbers - None

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) --
B. Compaction rate (mls/minute) 1.90
C. Sludge Volume Index (mls/gm) 199

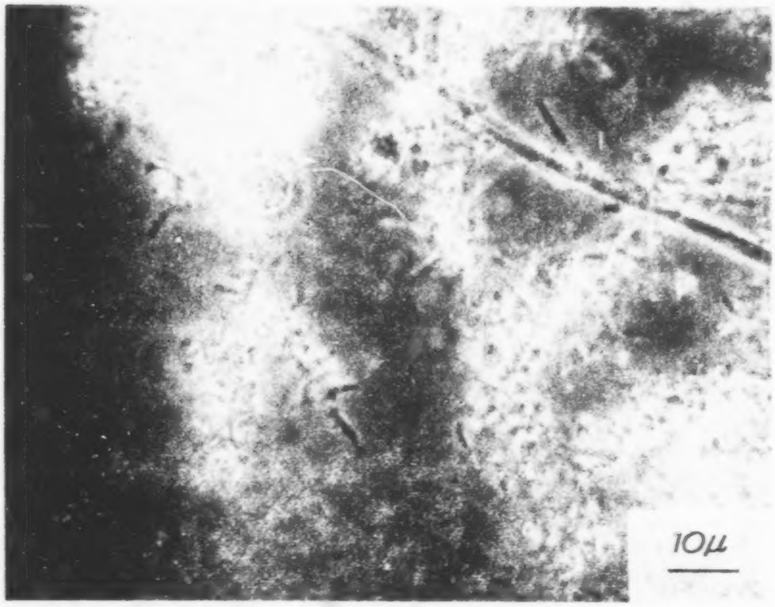
IV. Plant performance as indicated by:

A. Loading 0.139 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 14 mg/1
C. BOD reduction 98%

D. Type of waste - entirely from the manufacture of various dairy products

E. Special problems - loss of solids in effluent and production of foam in aeration tank; settled volume in laboratory was about 450 mls higher than that in the plant

100μ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Plant Location Borden's Dairy, #38
Woodstock, Illinois

Date November 2, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	nongeometric	nongeometric
B. Geometric mean	3,200 μ^2	4,300 μ^2
C. Standard deviation	2.0	2.2
D. No. counted per ml.	3,300,000	1,720,000
E. No. counted per gm.	508,000	265,000

F. Types of protozoans - rare flagellates

G. Types of invertebrates - numerous rotifers

H. Other observations - many small floc particles of medium density and with numerous small filaments (including Actinomyecetales); many dispersed colonies of Actinomycetales; rare fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Actinomycetales

B. Present in small numbers - None

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) --
B. Compaction rate (mls/minute) 0.50
C. Sludge Volume Index (mls/gm) 150

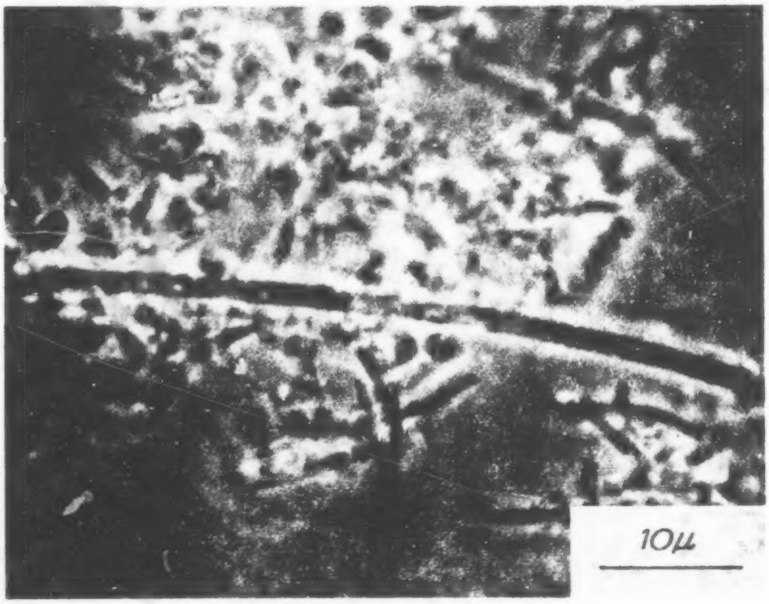
IV. Plant performance as indicated by:

A. Loading 0.130 $\frac{\text{lbs BOD/day}}{\text{lbs MLSS.}}$
B. Effluent BOD 10 mg/1
C. BOD reduction 99%

D. Type of waste - entirely from the manufacture of various dairy products

E. Special problems - very high concentration of solids in mixed liquor; foam produced in mixed liquor aeration tanks

20μ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Plant Location Borden's Dairy, #58
Woodstock, Illinois

Date May 16, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	1,080 μ^2	4,500 μ^2
C. Standard deviation	3.4	3.5
D. No. counted per ml.	3,660,000	1,720,000
E. No. counted per gm.	659,000	310,000

F. Types of protozoans - rare amoebas and free swimming ciliates

G. Types of invertebrates - none observed

H. Other observations - many small floc particles of medium density and with numerous small filaments (including Actinomycetales); few small colonies of Actinomycetales

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Actinomycetales

B. Present in small numbers - None

III. Settling characteristics of the sludge

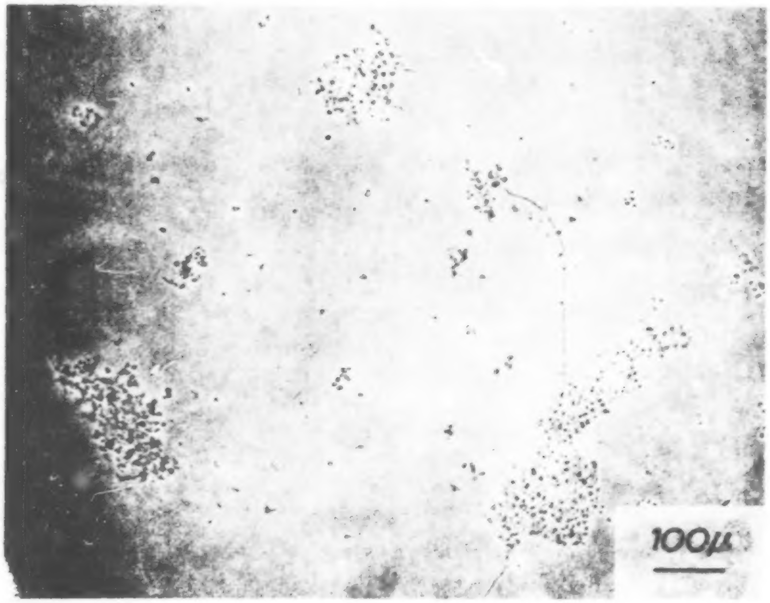
A. Settling rate (mls/minute) --
B. Compaction rate (mls/minute) 1.10
C. Sludge Volume Index (mls/gm) 122

IV. Plant performance as indicated by:

A. Loading $0.086 \ \frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 13 mg/l
C. BOD reduction 98%

D. Type of waste - entirely from the manufacture of various dairy products

E. Special problems - a 280 ml difference was obtained in the 30 min settled volume as compared to the data obtained at the plant; foam is produced in the mixed liquor aeration tanks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Plant Location Antioch, Illinois, #16

Date February 9, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	1,800 μ^2	20,000 μ^2
C. Standard deviation	3.8	3.9
D. No. counted per ml.	1,100,000	1,900,000
E. No. counted per gm.	451,000	800,000

F. Types of protozoans - numerous stalked ciliates, flagellates, and amoebas

G. Types of invertebrates - numerous rotifers

H. Other observations - many filaments attached to these rather small floc particles; moderate concentration of dispersed material; rare spirochaetes and fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus

B. Present in small numbers - Actinomycetales

III. Settling characteristics of the sludge

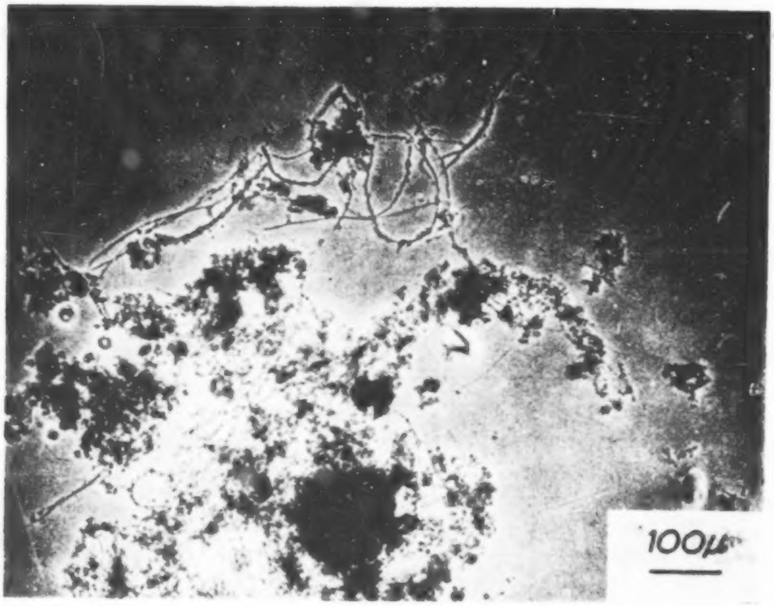
A. Settling rate (mls/minute) 124
B. Compaction rate (mls/minute) 0.70
C. Sludge Volume Index (mls/gm) 79

IV. Plant performance as indicated by:

A. Loading 0.290 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 73 mg/l
C. BOD reduction 52%

D. Type of waste - domestic and industrial (includes dairy waste and ink manufacture)

E. Special problems - none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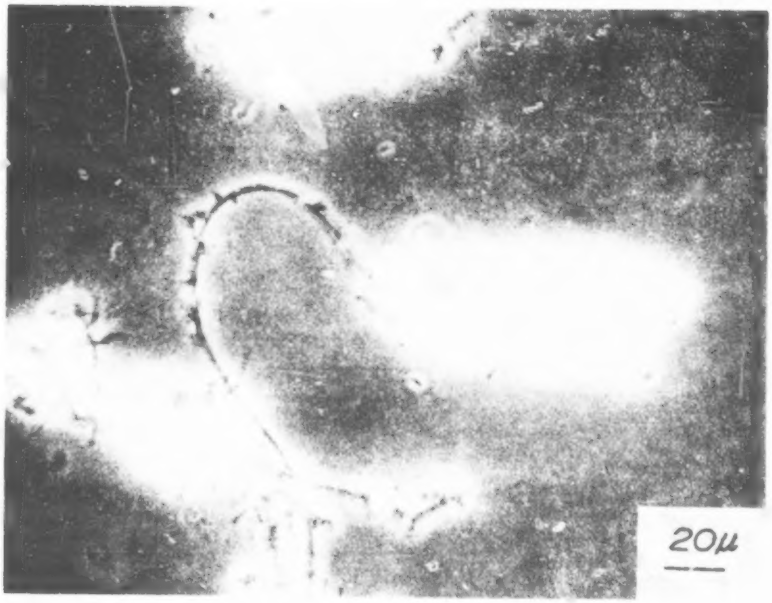
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Plant Location Antioch, Illinois, #26 Date July 11, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	3,000 μ^2	3,000 μ^2
C. Standard deviation	2.7	2.3
D. No. counted per ml.	1,640,000	1,210,000
E. No. counted per gm.	328,000	240,000

F. Types of protozoans - rare stalked ciliates, amoebas, and free swimming ciliates; rare flagellates

G. Types of invertebrates - numerous rotifers; rare nematodes

H. Other observations - medium to high density of floc particles with many small filaments; moderate concentration of dispersed material; few spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Beggiatoa

B. Present in small numbers - Actinomycetales

III. Settling characteristics of the sludge

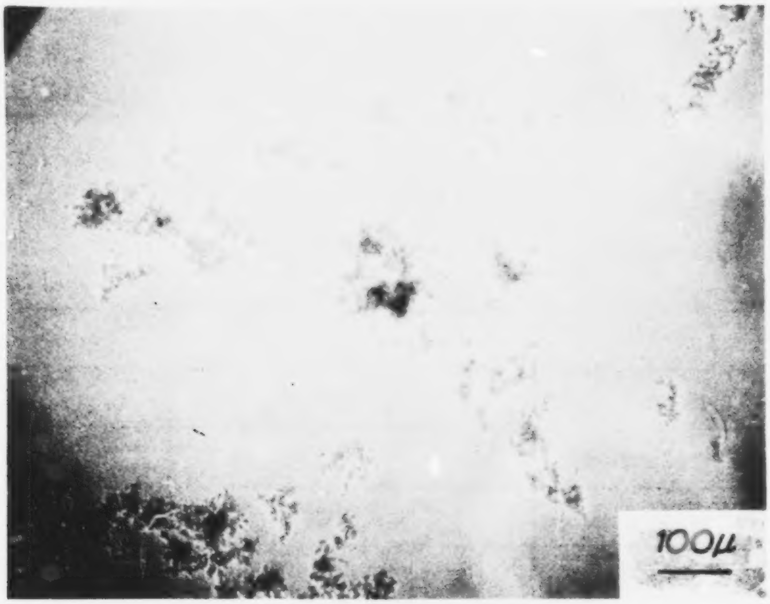
A. Settling rate (mls/minute) 210
B. Compaction rate (mls/minute) 0.72
C. Sludge Volume Index (mls/gm) 54

IV. Plant performance as indicated by:

A. Loading 0.214 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 7 mg/1
C. BOD reduction 97%

D. Type of waste - domestic and industrial (includes dairy waste and ink manufacture)

E. Special problems - none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Plant Location Antioch, Illinois, #39 Date November 9, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	3,000 μ^2	5,200 μ^2
C. Standard deviation	2.5	2.6
D. No. counted per ml.	949,000	653,000
E. No. counted per gm.	204,000	140,000

F. Types of protozoans - numerous stalked ciliates; rare flagellates, amoebas

G. Types of invertebrates - numerous rotifers

H. Other observations - compact sludge particles including some insect parts and rare filaments; moderate amount of dispersed material; rare fungal filaments, numerous spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - none

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 145
B. Compaction rate (mls/minute) 0.35
C. Sludge Volume Index (mls/gm) 46

IV. Plant performance as indicated by:

A. Loading 0.313 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 9 mg/l
C. BOD reduction 97%

D. Type of waste - domestic and industrial (includes dairy waste and ink manufacture)
E. Special problems - none

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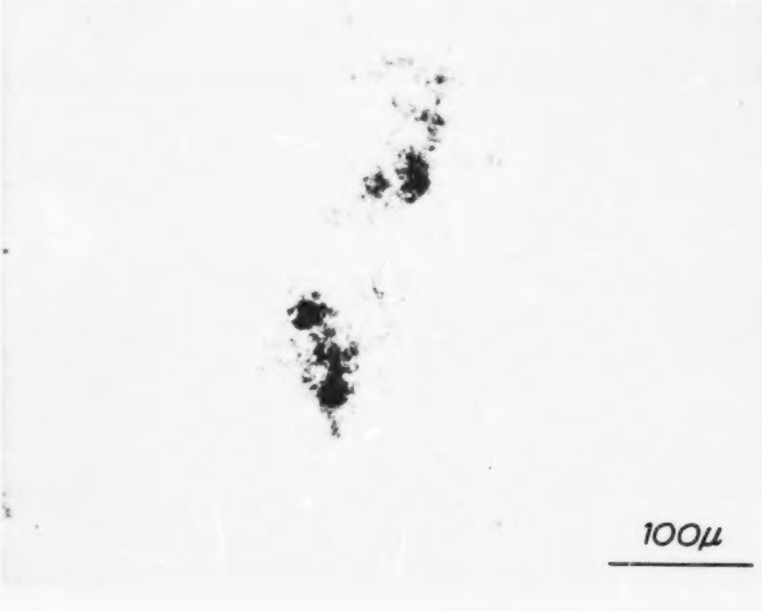
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Plant Location Antioch, Illinois #54　　　Date April 11, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	3,400 μ^2	8,100 μ^2
C. Standard deviation	2.5	2.1
D. No. counted per ml.	1,630,000	5,330,000
E. No. counted per gm.	631,000	2,060,000

F. Types of protozoans - numerous stalked ciliates, flagellates and free swimming ciliates; rare amoebas

G. Types of invertebrates - numerous rotifers

H. Other observations - medium density floc particles with numerous filaments, large and small; moderate amount of dispersed material; few fungal filaments; rare spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Actinomycetales, Beggiatoa

B. Present in small numbers - Bacillus

III. Settling characteristics of the sludge

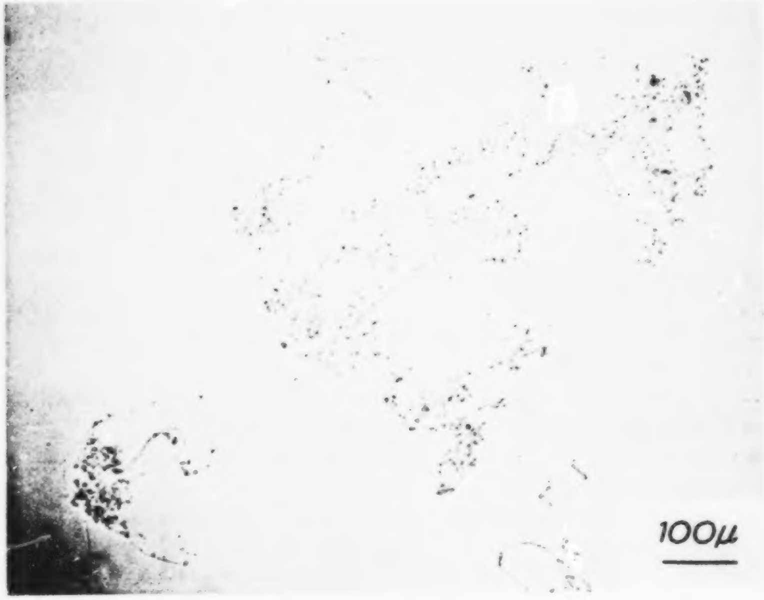
A. Settling rate (mls/minute) 14
B. Compaction rate (mls/minute) 3.90
C. Sludge Volume Index (mls/gm) 296

IV. Plant performance as indicated by:

A. Loading 0.291 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 7 mg/l
C. BOD reduction 96%

D. Type of waste - domestic and industrial (includes dairy waste and ink manufacture)

E. Special problems - some inadequacy in return sludge capacity at this time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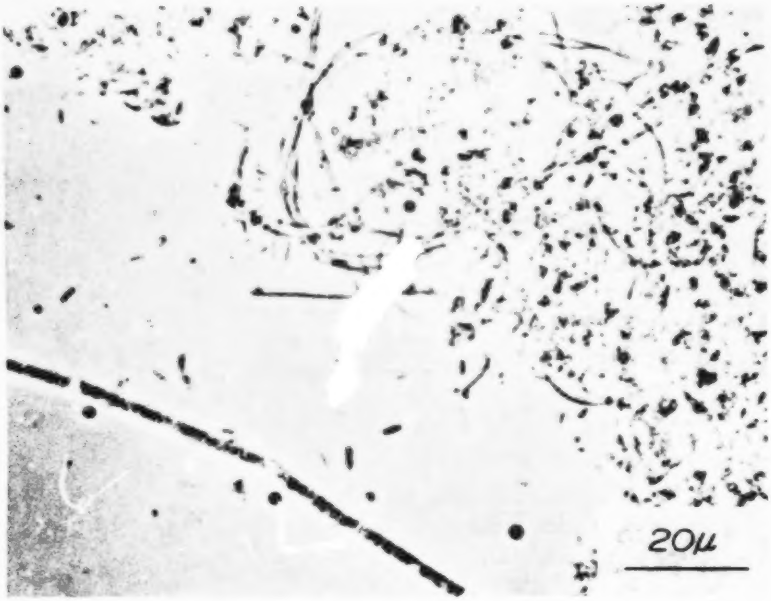
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Plant Location North Shore, Clavey Road, Illinois, #17

Date February 23, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	3,600 μ^2	8,300 μ^2
C. Standard deviation	3.1	2.5
D. No. counted per ml.	528,000	498,000
E. No. counted per gm.	177,000	170,000

F. Types of protozoans - rare stalked ciliates, flagellates, and free swimming ciliates

G. Types of invertebrates - none observed

H. Other observations - compact, medium size floc particles with few filaments; moderate concentration of dispersed material

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus

B. Present in small numbers - Actinomycetales

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 240
B. Compaction rate (mls/minute) 0.38
C. Sludge Volume Index (mls/gm) 44

IV. Plant performance as indicated by:

A. Loading 0.853 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 15 mg/1
C. BOD reduction 97%

D. Type of waste - domestic and industrial (dairy waste and cosmetic manufacture)

E. Special problems - occasional billowing sludge and septic sludge

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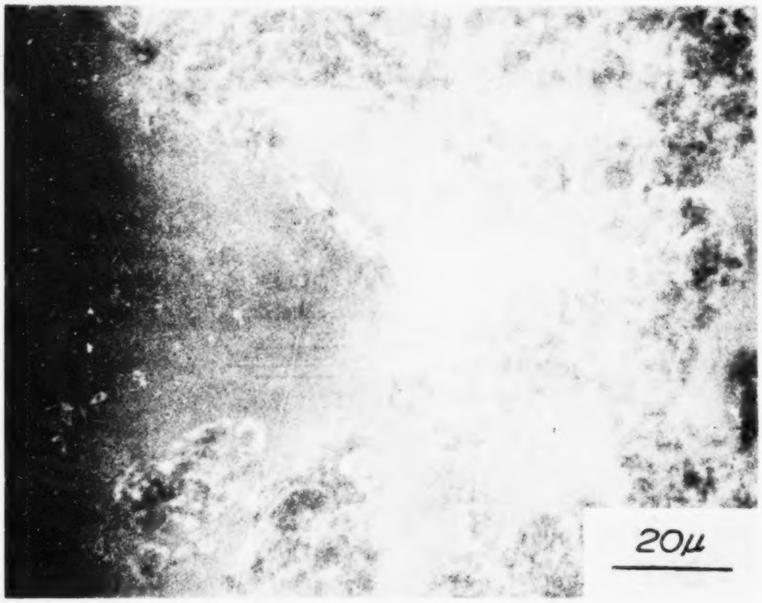
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Plant Location North Shore, Clavey Road, Illinois, #34

Date September 19, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	3,000 μ^2	6,800 μ^2
C. Standard deviation	2.4	2.4
D. No. counted per ml.	1,340,000	588,000
E. No. counted per gm.	430,000	190,000

F. Types of protozoans - numerous stalked ciliates and flagellates; rare amoebas

G. Types of invertebrates - numerous rotifers

H. Other observations - high density floc particles with few filaments; medium concentration of dispersed material, rare fungal filaments and spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Sphaerotilus

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

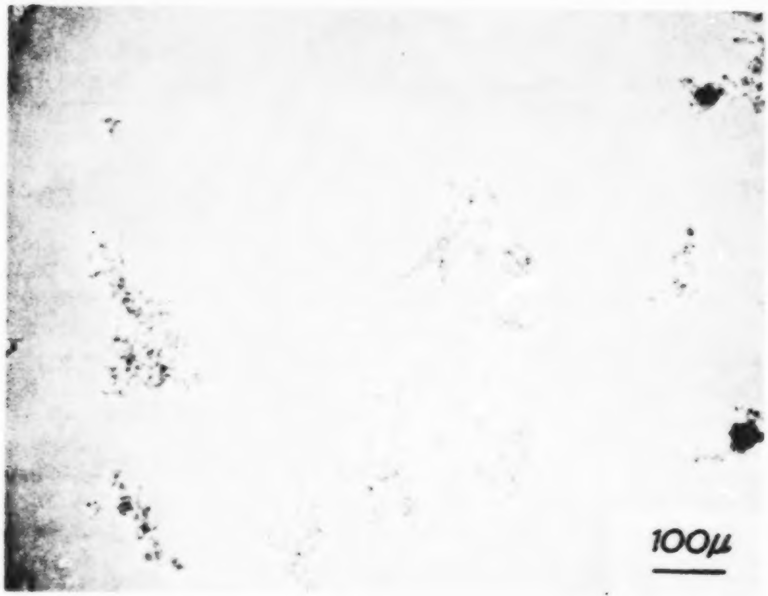
A. Settling rate (mls/minute) 690
B. Compaction rate (mls/minute) 0.15
C. Sludge Volume Index (mls/gm) 36

IV. Plant performance as indicated by:

A. Loading 0.554 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$.
B. Effluent BOD 9 mg/l
C. BOD reduction 98%

D. Type of waste - domestic and industrial (dairy waste and cosmetic manufacture)

E. Special problems - occasional billowing sludge and septic sludge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Plant Location North Shore, Clavey Road, Illinois, #36

Date October 19, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	3,700 μ^2	9,300 μ^2
C. Standard deviation	2.5	2.3
D. No. counted per ml.	595,000	260,000
E. No. counted per gm.	166,000	70,000

F. Types of protozoans - numerous stalked ciliates and flagellates; rare amoebas and free swimming ciliates

G. Types of invertebrates - numerous rotifers

H. Other observations - high-density floc particles of various sizes and with rare filaments; moderate concentration of dispersed material

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Sphaerotilus

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

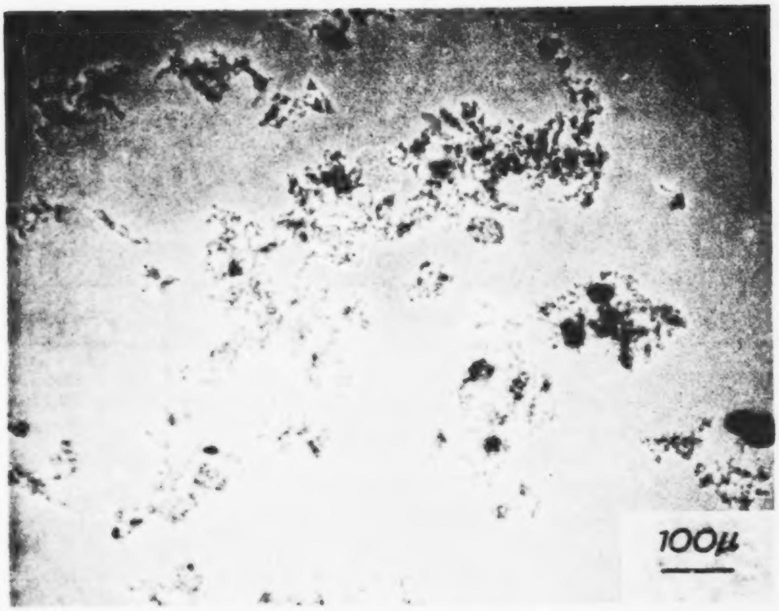
A. Settling rate (mls/minute) 1050
B. Compaction rate (mls/minute) 0.24
C. Sludge Volume Index (mls/gm) 41

IV. Plant performance as indicated by:

A. Loading 0.227 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 9 mg/1
C. BOD reduction 95%

D. Type of waste - domestic and industrial (dairy waste and cosmetic manufacture)

E. Special problems - occasional billowing sludge and septic sludge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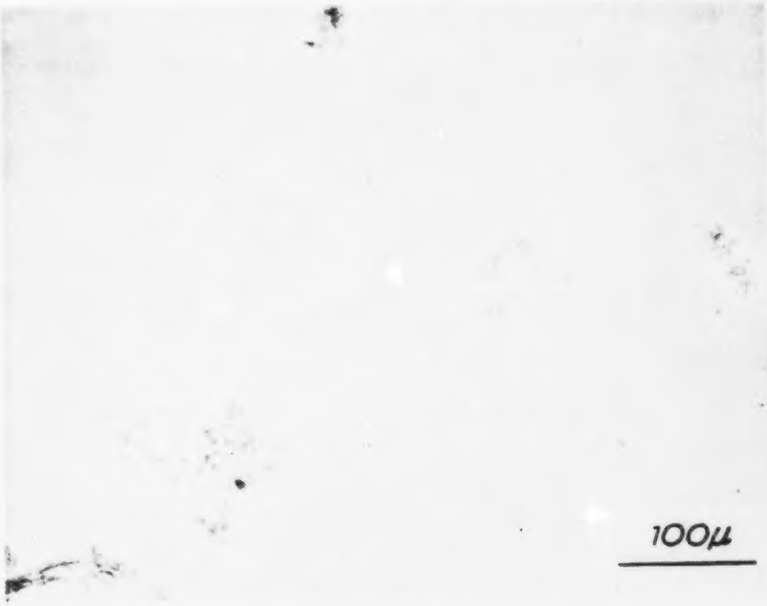
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Plant Location North Shore, Clavey Road, Illinois, #59 Date June 6, 1968

I. Microscopic Observations

		Particles	Filaments
A.	Distribution	geometric normal	geometric normal
B.	Geometric mean	3,520 μ^2	6,750 μ^2
C.	Standard deviation	2.2	2.2
D.	No. counted per ml.	818,000	343,000
E.	No. counted per gm.	214,000	90,000

F. Types of protozoans - numerous stalked ciliates, flagellates, and free swimming ciliates

G. Types of invertebrates - none observed

H. Other observations - medium to high density floc particles of various sizes and with rare filaments; medium concentration of dispersed material; rare fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Actinomycetales

B. Present in small numbers - Sphaerotilus

III. Settling characteristics of the sludge

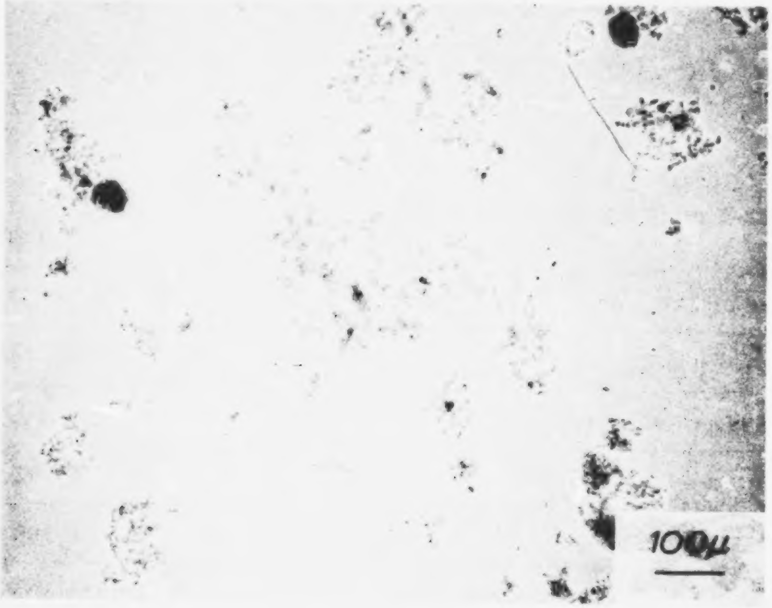
A. Settling rate (mls/minute) 320
B. Compaction rate (mls/minute) 0.421
C. Sludge Volume Index (mls/gm) 42

IV. Plant performance as indicated by:

A. Loading 0.182 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 75 mg/l
C. BOD reduction 47%

D. Type of waste - domestic and industrial (dairy waste and cosmetic manufacture)

E. Special problems - occasional billowing sludge and septic sludge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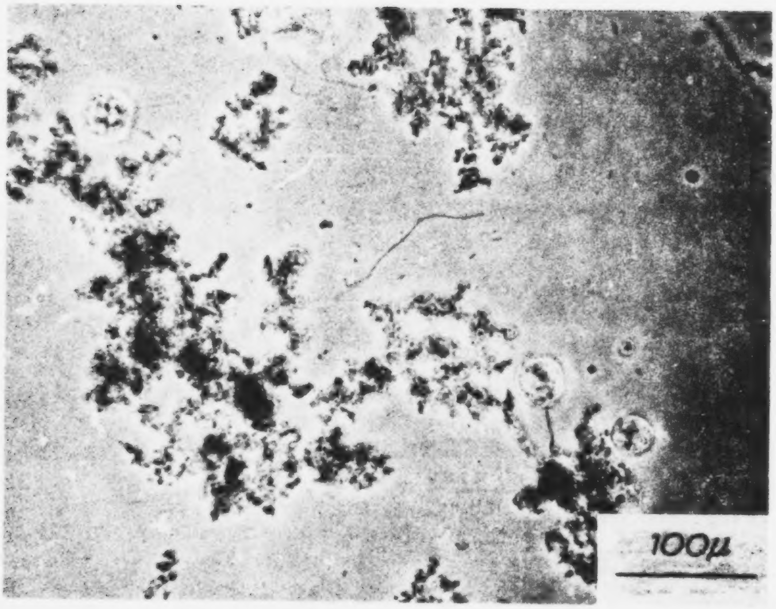
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Plant Location Gary, Indiana, #18 Date March 9, 1967

I. Microscopic Observations

		Particles	Filaments
A.	Distribution	geometric normal	geometric normal
B.	Geometric mean	1,600 μ^2	5,100 μ^2
C.	Standard deviation	3.2	3.0
D.	No. counted per ml.	3,120,000	18 5,180,000
E.	No. counted per gm.	1,060,000	1,760,000

F. Types of protozoans - rare stalked ciliates

G. Types of invertebrates - none observed

H. Other observations - small, highly filamentous floc particles of medium density, medium concentration of dispersed material; rare fungal filaments, numerous spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus

B. Present in small numbers - Actinomycetales, Sphaerotilus

III. Settling characteristics of the sludge

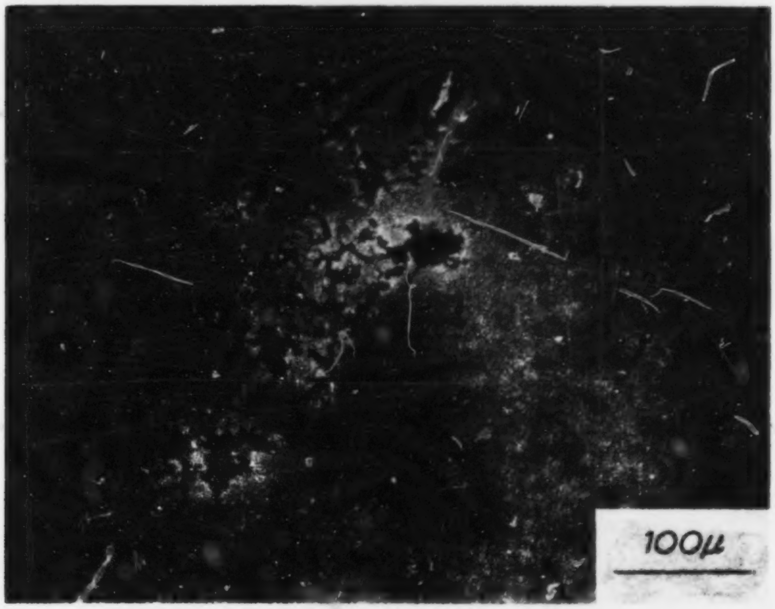
A. Settling rate (mls/minute) 26
B. Compaction rate (mls/minute) 2.20
C. Sludge Volume Index (mls/gm) 374

IV. Plant performance as indicated by:

A. Loading $0.051 \ \frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 10 mg/1
C. BOD reduction 82%

D. Type of waste - domestic and industrial (includes waste from coke plant and chicken processing plant)

E. Special problems - no persistent problems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Plant Location Gary, Indiana, #29 Date August 1, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	1,900 μ^2	6,000 μ^2
C. Standard deviation	3.7	3.3
D. No. counted per ml.	2,040,000	630,000
E. No. counted per gm.	304,000	90,000

F. Types of protozoans- rare flagellates

G. Types of invertebrates - none observed

H. Other observations- very dark, highly dense floc particles; medium concentration of dispersed material mostly bacteria; rare fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Beggiatoa

B. Present in small numbers - Actinomycetales

III. Settling characteristics of the sludge

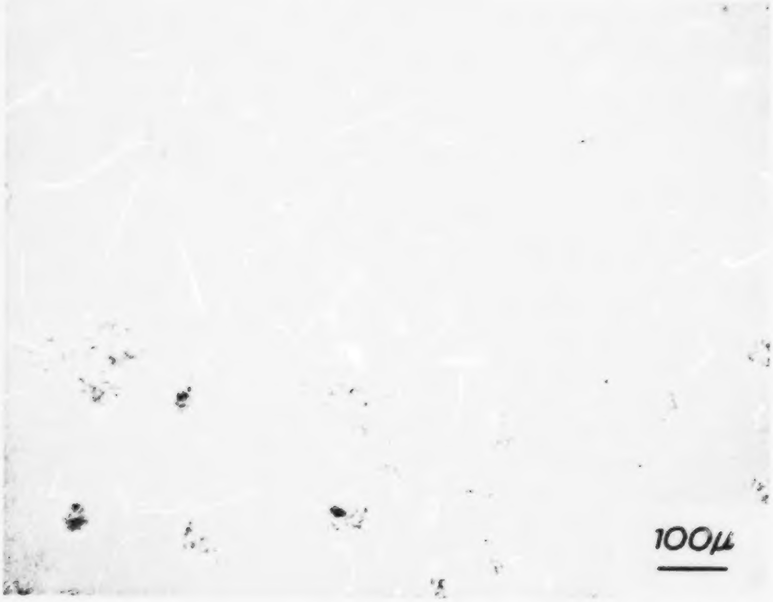
A. Settling rate (mls/minute) 100
B. Compaction rate (mls/minute) 0.80
C. Sludge Volume Index (mls/gm) 42

IV. Plant performance as indicated by:

A. Loading 0.029 $\frac{\text{lbs BOD/day}}{\text{lb MLSS.}}$
B. Effluent BOD 35 mg/l
C. BOD reduction 50%

D. Type of waste - domestic and industrial (includes waste from chicken processing plant)

E. Special problems - no persistent problems; coke wastes are no longer treated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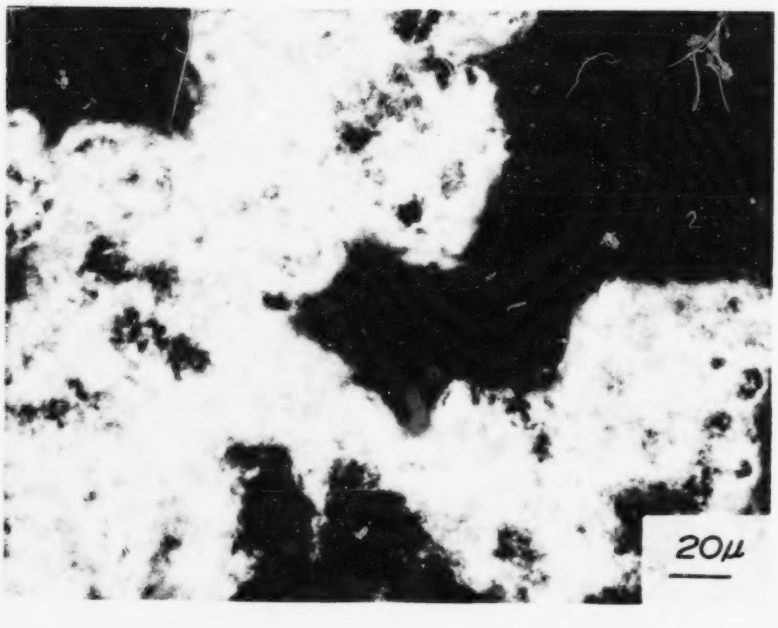
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Plant Location Gary, Indiana, #35 Date October 12, 1967

I. Microscopic Observations

		Particles	Filaments
A.	Distribution	geometric normal	geometric normal
B.	Geometric mean	2,400 μ^2	5,700 μ^2
C.	Standard deviation	2.3	2.5
D.	No. counted per ml.	1,300,000	190,000
E.	No. counted per gm.	377,000	60,000

F. Types of protozoans - numerous stalked ciliates and free swimming ciliates; rare flagellates and amoebas

G. Types of invertebrates - numerous rotifers

H. Other observations - very dark, highly dense floc particles with rare filaments; medium concentration of dispersed material

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Beggiatoa

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

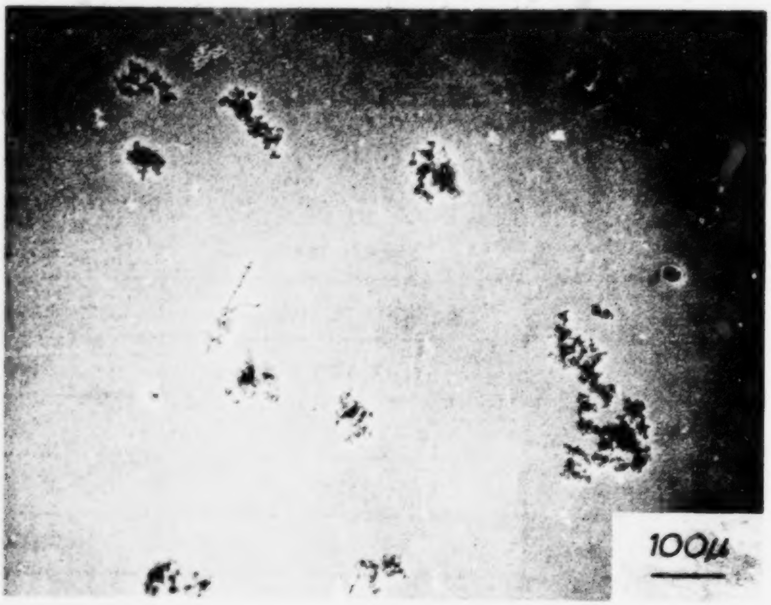
A. Settling rate (mls/minute) 1000
B. Compaction rate (mls/minute) 0.29
C. Sludge Volume Index (mls/gm) 42

IV. Plant performance as indicated by:

A. Loading 0.060 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 10 mg/l
C. BOD reduction 87%

D. Type of waste - domestic and industrial (includes waste from chicken processing plant)

E. Special problems - no persistent problems; coke wastes are no longer treated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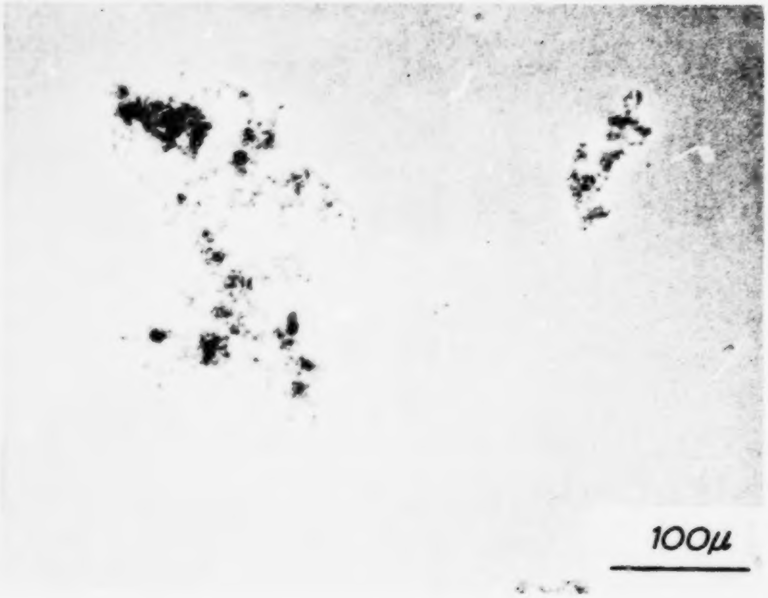
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Plant Location Gary, Indiana, #56 Date April 25, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	$3{,}200\ \mu^2$	$5{,}030\ \mu^2$
C. Standard deviation	2.4	2.5
D. No. counted per ml.	1,680,000	1,510,000
E. No. counted per gm.	318,000	280,000

F. Types of protozoans - numerous stalked ciliates, flagellates, amoebas, and free swimming ciliates

G. Types of invertebrates - numerous rotifers

H. Other observations - many small compact floc particles with few filaments; medium concentration of dispersed material; rare fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Sphaerotilus

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

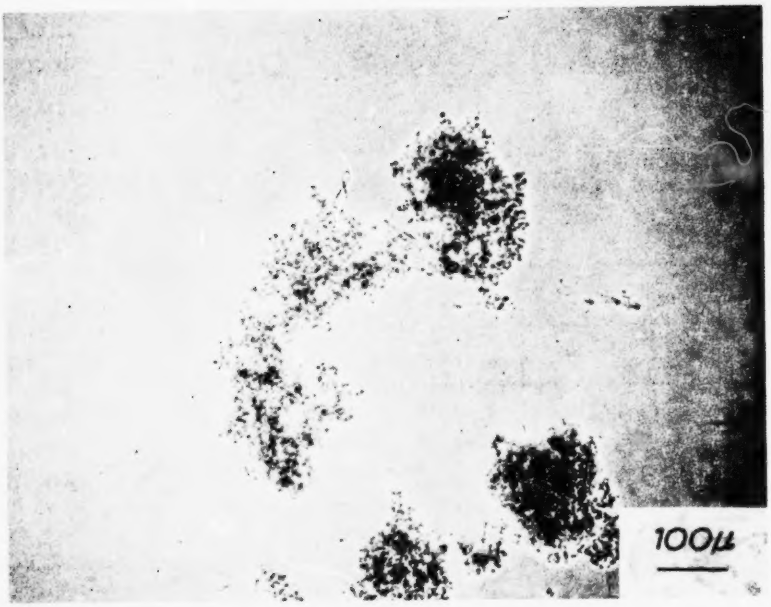
A. Settling rate (mls/minute) 31
B. Compaction rate (mls/minute) 2.30
C. Sludge Volume Index (mls/gm) 102

IV. Plant performance as indicated by:

A. Loading 0.027 $\frac{\text{lb BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 14 mg/1
C. BOD reduction 73%

D. Type of waste - domestic and industrial (includes waste from chicken processing plant)

E. Special problems - no persistent problems; coke wastes are no longer treated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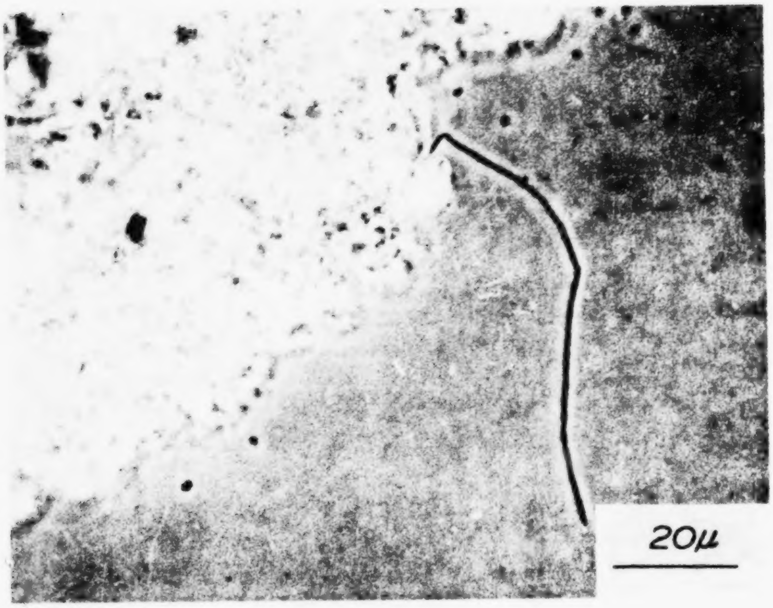
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Plant Location Hanover Park, Illinois, #41 Date December 7, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	6,200 μ^2	14,000 μ^2
C. Standard deviation	2.6	2.6
D. No. counted per ml.	244,000	2,090,000
E. No. counted per gm.	136,000	1,170,000

F. Types of protozoans - numerous stalked ciliates, flagellates, and amoebas

G. Types of invertebrates - numerous rotifers

H. Other observations - compact sludge particles of various sizes with numerous attached small and large filaments; rare spirochaetes.

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Actinomycetales, Arthrobacter, Caryophanon

B. Present in small numbers - Bacillus, Sphaerotilus

III. Settling characteristics of the sludge

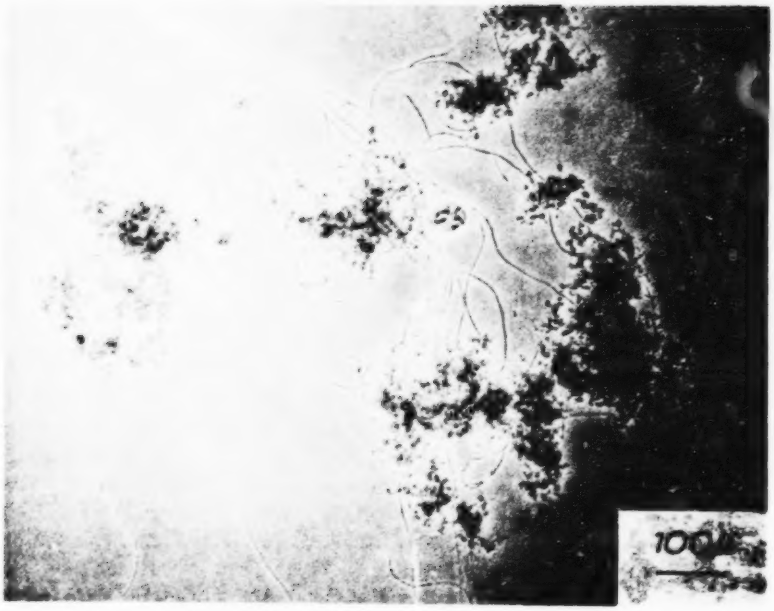
A. Settling rate (mls/minute) 220
B. Compaction rate (mls/minute) 0.40
C. Sludge Volume Index (mls/gm) 123

IV. Plant performance as indicated by:

A. Loading 0.456 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 21 mg/l
C. BOD reduction 90%

D. Type of waste - domestic

E. Special problems - chronic bulking in dry weather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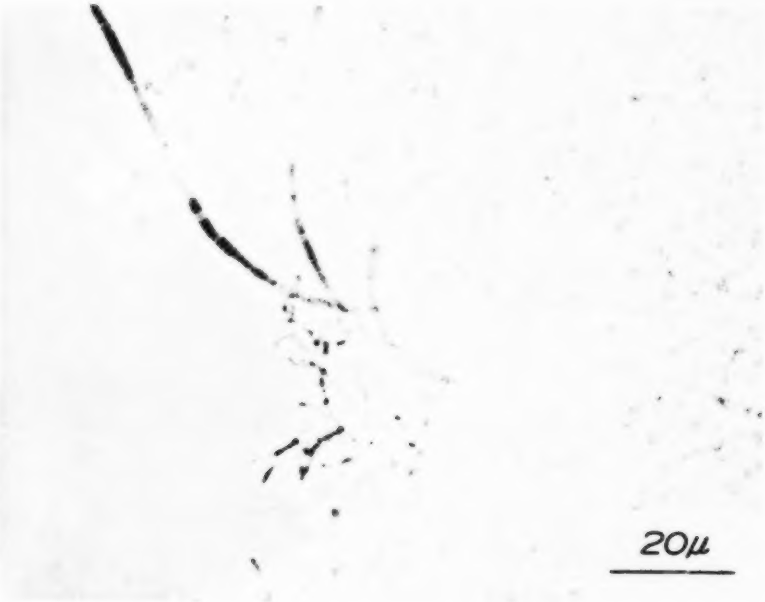
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Plant Location Hanover Park, Illinois, #49 Date February 22, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	2,800 μ^2	17,200 μ^2
C. Standard deviation	3.5	3.9
D. No. counted per ml.	240,000	2,340,000
E. No. counted per gm.	186,000	1,810,000

F. Types of protozoans - numerous stalked ciliates, flagellates and amoebas

G. Types of invertebrates - numerous rotifers; rare nematodes

H. Other observations - low to medium density floc particles with numerous filaments; medium concentration of dispersed material; few fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Actinomycetales, Sphaerotilus, Arthrobacter

B. Present in small numbers - Bacillus

III. Settling characteristics of the sludge

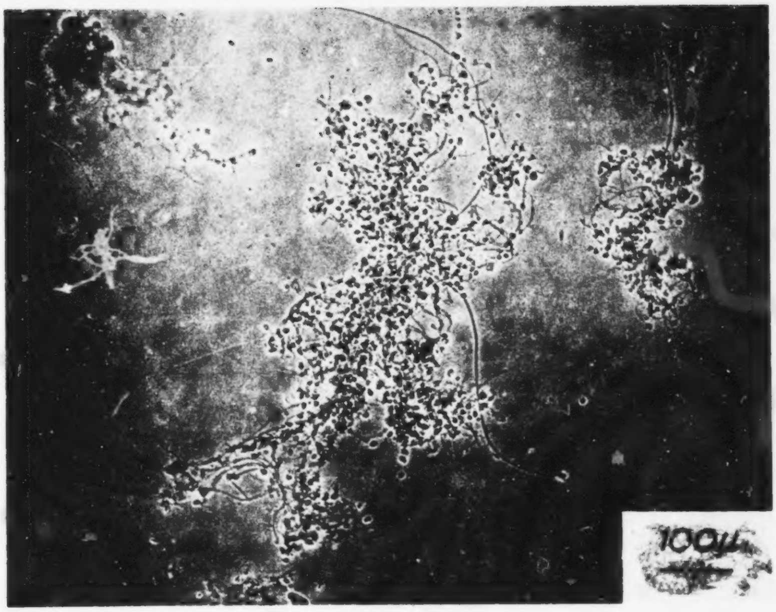
A. Settling rate (mls/minute) 48
B. Compaction rate (mls/minute) 1.10
C. Sludge Volume Index (mls/gm) 336

IV. Plant performance as indicated by:

A. Loading 0.444 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 19 mg/1
C. BOD reduction 88%

D. Type of waste - domestic

E. Special problems - chronic bulking in dry weather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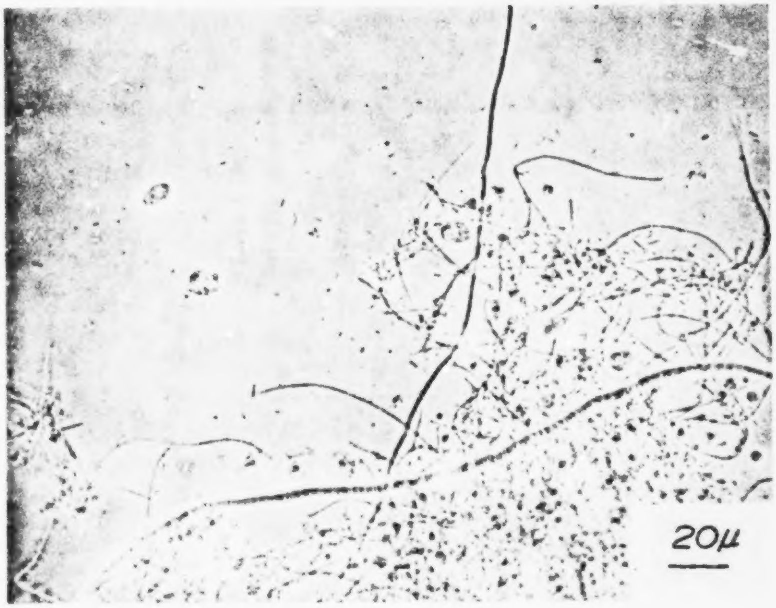
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Plant Location Hanover Park, Illinois, #57 Date May 2, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	3,100 μ^2	11,000 μ^2
C. Standard deviation	3.3	2.5
D. No. counted per ml.	373,000	3,200,000
E. No. counted per gm.	263,000	2,250,000

F. Types of protozoans - numerous stalked ciliates, flagellates, and amoebas

G. Types of invertebrates - none observed

H. Other observations - medium to low density highly filamentous floc particles; moderate concentration of dispersed material

II. Filamentous organisms isolated from sludge

A. Present in significant numbers Bacillus, Actinomycetales, Sphaerotilus

B. Present in small numbers - None

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 67

B. Compaction rate (mls/minute) --

C. Sludge Volume Index (mls/gm) 141

IV. Plant performance as indicated by:

A. Loading 0.273 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$

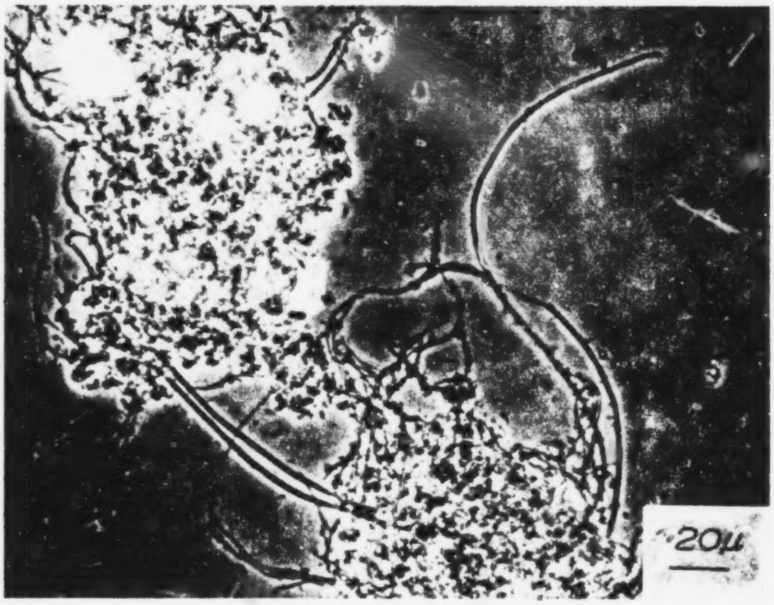
B. Effluent BOD 19 mg/l

C. BOD reduction 82%

D. Type of waste - domestic

E. Special problems - rising sludge obtained in settling test after 30 minutes; chronic bulking in dry weather

100μ


20μ

Plant Location Hanover Park, Illinois, #63 Date July 25, 1968

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	5,000 μ^2	7,700 μ^2
C. Standard deviation	30.4	7.92
D. No. counted per ml.	138,000	3,190,000
E. No. counted per gm.	72,800	1,690,000

F. Types of protozoans - numerous stalked ciliates, flagellates, amoebas, and free swimming ciliates

G. Types of invertebrates - numerous rotifers and nematodes

H. Other observations - medium to low density floc particles with numerous filaments; moderate concentration of dispersed material; very rare fungal filaments; rare spirochaetes and zoogleal formation

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Bacillus, Sphaerotilus, Arthrobacter

B. Present in small numbers - Actinomycetales

III. Settling characteristics of the sludge

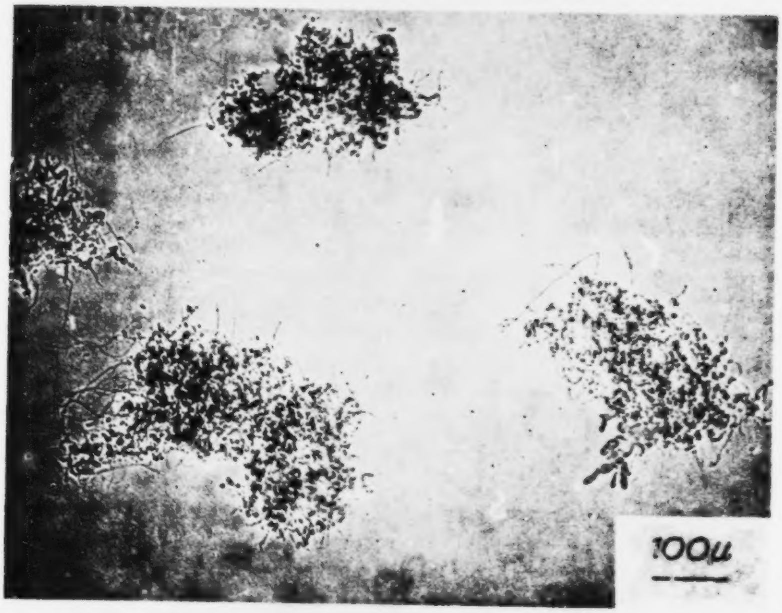
A. Settling rate (mls/minute) 99
B. Compaction rate (mls/minute) 1.09
C. Sludge Volume Index (mls/gm) 156

IV. Plant performance as indicated by:

A. Loading 0.130 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 7.92 mg/l
C. BOD reduction 88%

D. Type of waste - domestic

E. Special problems - chronic bulking in dry weather; the process now includes continuous wasting of activated sludge into the primary clarifier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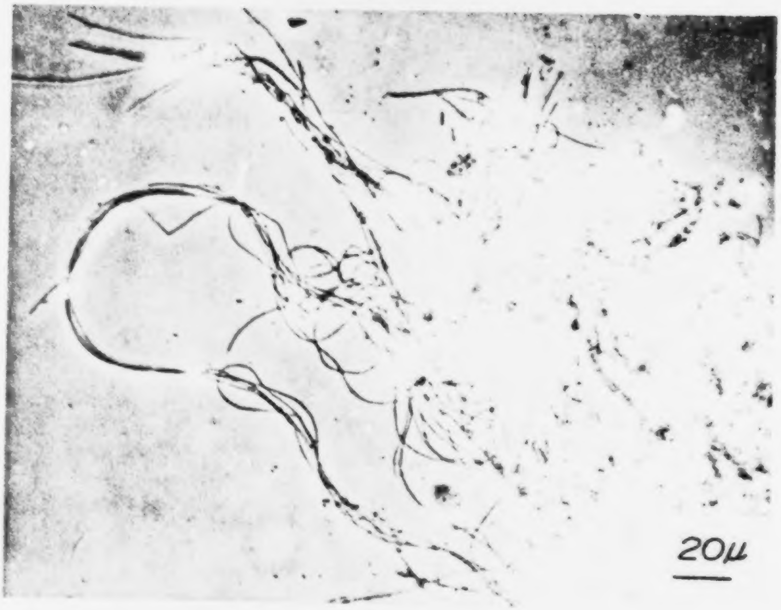
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Plant Location Carol Stream #1 Date September 8, 1966

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	5,900 μ^2	15,000 μ^2
C. Standard deviation	2.9	2.2
D. No. counted per ml.	380,000	512,000
E. No. counted per gm.	111,000	150,000

F. Types of protozoans - numerous flagellates and amoebas

G. Types of invertebrates - none

H. Other observations - many large, ragged floc particles; moderate concentration of dispersed material; rare spirochaete organisms

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - Actinomycetales

B. Present in small numbers - Bacillus

III. Settling characteristics of the sludge

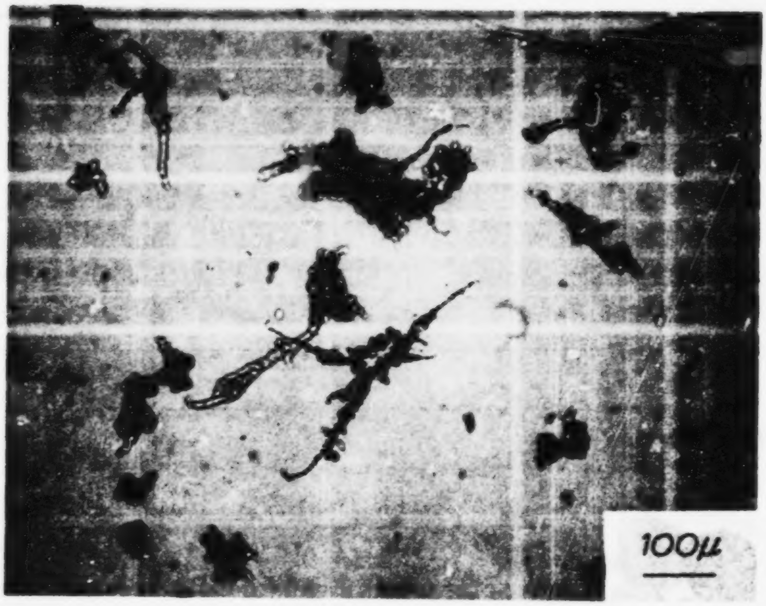
A. Settling rate (mls/minute) 160
B. Compaction rate (mls/minute) 0.41
C. Sludge Volume Index (mls/gm) 47

IV. Plant performance as indicated by:

A. Loading 0.392 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 78 mg/l
C. BOD reduction 59%

D. Type of waste - domestic and industrial (a printing plant gives a white precipitate)

E. Special problems -
1. Plant receives two times the designed loading capacity
2. The aeration was cut off for six hours previous to the time of sampling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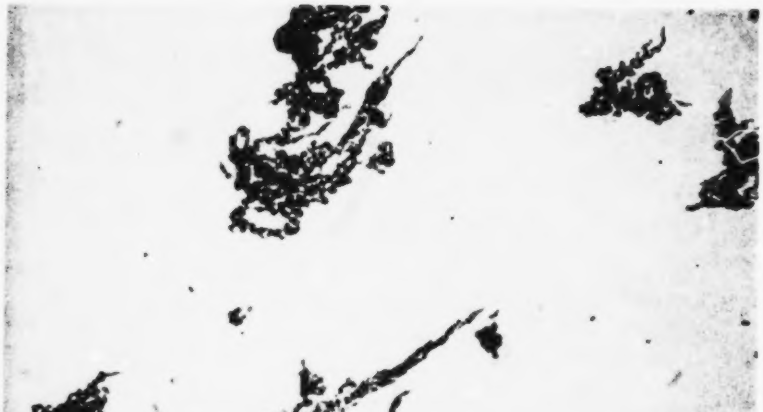


Plant Location Crystal Lake, Illinois, #2 Date September 15, 1966

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	--
B. Geometric mean	5,300 μ^2	--
C. Standard deviation	8.3	--
D. No. counted per ml.	76,000	10,000
E. No. counted per gm.	64,000	10,000

F. Types of protozoans - rare stalked ciliates and numerous flagellates and amoebas

G. Types of invertebrates - rotifers rarely seen

H. Other observations - many large ragged floc particles, moderate concentration of dispersed materials

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - none

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 600
B. Compaction rate (mls/minute) 0.09
C. Sludge Volume Index (mls/gm) 67

IV. Plant performance as indicated by:

A. Loading --
B. Effluent BOD 32 mg/l
C. BOD reduction 76%

D. Type of waste - major domestic, minor industrial

E. Special problems - the plant has experienced some loss of solids in the secondary clarifier due to hydraulic overload

100µ

20µ

Plant Location Fox River Grove, Illinois, #4 Date September 29, 1966

I. Microscopic Observations

	Particles	Filaments
A. Distribution	--	-
B. Geometric mean	--	--
C. Standard deviation	--	--
D. No. counted per ml.	numerous small particles	--
E. No. counted per gm.	numerous small particles	--

F. Types of protozoans - none observed

G. Types of invertebrates - none observed

H. Other observations - very small floc particles and moderate concentration of dispersed material; numerous fungal filaments

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - None

B. Present in small numbers - Bacillus, Actinomycetales

III. Settling characteristics of the sludge

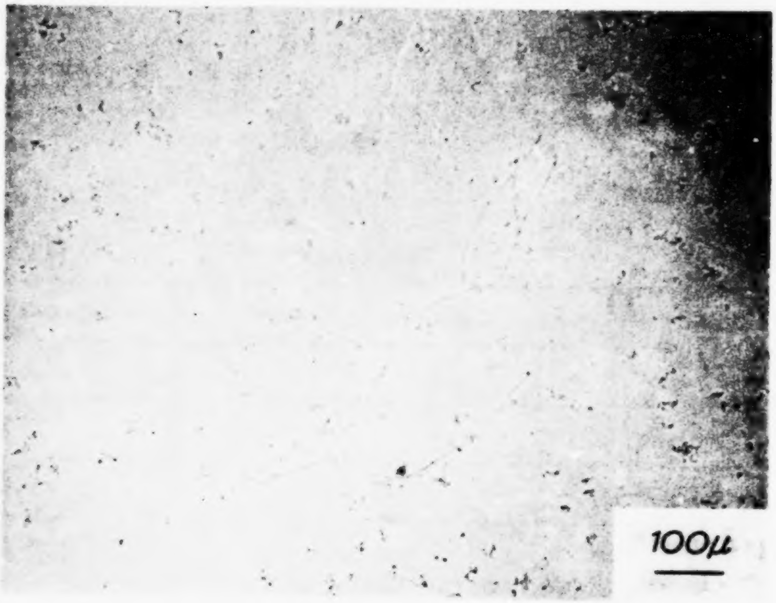
A. Settling rate (mls/minute) 64
B. Compaction rate (mls/minute) 0.77
C. Sludge Volume Index (mls/gm) 159

IV. Plant performance as indicated by:

A. Loading 0.148 $\frac{\text{lbs BOD/day}}{\text{lb MLSS}}$
B. Effluent BOD 31 mg/l
C. BOD reduction 33%

D. Type of waste - domestic and industrial (includes acids, heavy metals, and dyes)

E. Special problems - low pH in the process and the loss of very fine suspended solids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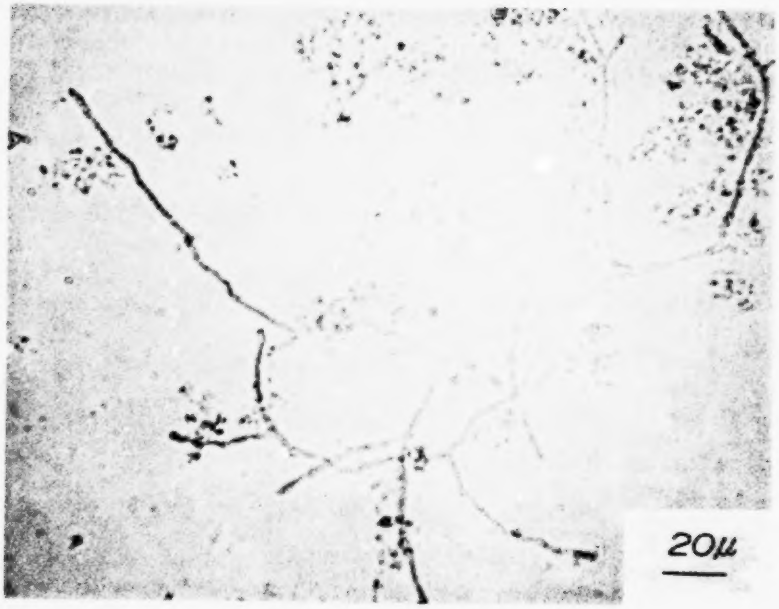

20µ

Plant Location Chicago, W.S.W., #33

Date September 5, 1967

I. Microscopic Observations

	Particles	Filaments
A. Distribution	geometric normal	geometric normal
B. Geometric mean	6,200 μ^2	18,300 μ^2
C. Standard deviation	3.0	2.2
D. No. counted per ml.	308,000	728,000
E. No. counted per gm.	103,000	240,000

F. Types of protozoans - numerous stalked ciliates; flagellates, amoebas and free swimming ciliates

G. Types of invertebrates - numerous rotifers

H. Other observations - high density floc particles of various size and with few filaments; medium concentration of dispersed material; numerous spirochaetes

II. Filamentous organisms isolated from sludge

A. Present in significant numbers - none

B. Present in small numbers - Bacillus, Actinomycetales, Beggiatoa

III. Settling characteristics of the sludge

A. Settling rate (mls/minute) 107
B. Compaction rate (mls/minute) 0.42
C. Sludge Volume Index (mls/gm) 86

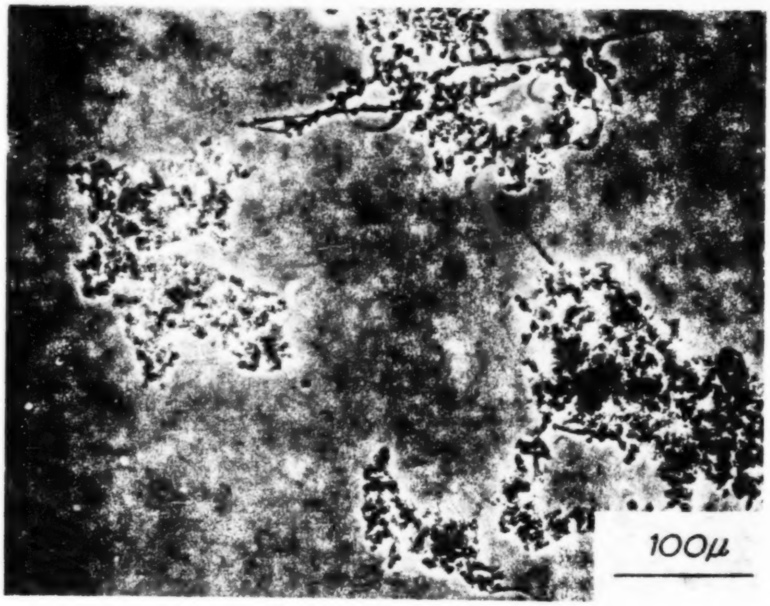
IV. Plant performance as indicated by:

A. Loading --
B. Effluent BOD 2 mg/l
C. BOD reduction 98%

D. Type of waste - domestic and industrial

E. Special problems - periodic problems with bulking

100μ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INFORMATION FROM MICROSCOPIC EXAMINATION OF ACTIVATED SLUDGE

Introduction

Microscopic examination of mixed liquor has been used as an aid to operational control of activated sludge processes sporadically for many years. Operators study the sludge from their own plant over a period of time and develop a subjective concept of how the sludge should look when the process is generating properly. They usually use terms like "healthy," "fat," or "sick," to describe the appearance of the sludge. On this basis, they develop an intuitive correlation between the appearance of the sludge under the microscope and the performance of the process and can predict the development of operating problems. However, on this subjective basis of examination, each activated sludge process is unique and a feel for the microscopic appearance of sludge in one plant is not translatable to other plants.

A number of research scientists and engineers have also attempted to assess the value of microscopic examination as a method for determining the condition of the sludge. Much of the emphasis in these investigations has been upon the types and numbers of protozoa present. Buswell and Long (1), Agersborg and Hatfield (2), and Barritt (3) noted that there was a definite succession of protozoa during the start-up phase of an activated sludge process. They found that initially flagellated and amoeboid protozoa predominated but with increased development of the floc the flagellates give way to free-swimming ciliates. As the activated sludge reached peak efficiency, the stalked ciliates come to predominate over the free-swimming ciliates. McKinney and Gram (4) confirmed these observations and also suggested that rotifers would replace the stalked ciliates as the predominant animal life in the process when the sludge reached an even higher degree of oxidation. However, Lackey (5) and Jenkins (6) found that there was little correlation between the protozoan population and the degree of purification. This conclusion was further substantiated by the work of Baines et al (7). Cramer (8) put forth the concept that protozoa were essential for optimum purification and that routine microscopic examinations for the presence of stalked ciliates could be used as an index of a well-operating process.

The appearance of the floc particles themselves has been the subject of only a few studies. Heukelekian and Weisberg (9) described some floc particles as diffuse with ragged edges while others were compact with distinct margins. The compact sludge particles were said to be present in processes with well-flocculated sludge which gave a high treatment efficiency. Hawkes (10) stated that the size, shape, and structure of individual floc particles and the relative sizes of the different particles are important features to be observed during microscopic examination of activated sludge. In addition to describing how to distinguish a well-flocculated sludge from a poorly flocculated sludge, he also noted that there should be no dispersed solids in the interstitial liquor. The dis-

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persed solids could be either individual bacterial cells or small particles of organic matter from the waste. In either case these dispersed solids would not be separated in the secondary sedimentation process and would have an adverse effect on effluent quality. Large tassel-like flocs were also described as being associated with poor treatment efficiency.

Butterfield (11) originally described the typical colonies of Zoogloea ramigeria which can be identified on the basis of their microscopic morphology alone. He was of the opinion that this bacterium was responsible for most of the BOD reduction which occurs in the activated sludge process. More recently, there has been controversy about the validity of Zoogloea ramigeria as a species and some authorities have called all flocculated bacteria "zoogloea." It is now generally accepted that Zoogloea is a valid genus and also that most other bacteria can flocculate under the proper conditions.

Filamentous bacteria have been recognized in activated sludge for many years. Most of the filamentous bacteria which have been observed in activated sludge have been called "sphaerotilus" without any attempt at adequate identification and "sphaerotilus" has been cited as the cause of bulking. Sphaerotilus natans is sometimes present in activated sludge but there is no reason to assume that it is the only filamentous bacterium present. Finstein and Heukelekian (13) counted and measured bacterial filaments in several samples from three different activated sludge plants. They found that the total length of filaments attached to floc particles was directly proportional to the sludge volume index. They also noted that floc size was not related to sludge volume index but that filaments were more likely to be associated with large floc particles than with small ones. Thus, the association of filamentous bacteria with bulking is well established. However, the identities of the various filamentous bacteria which grow in activated sludge have not been determined and the cause of excessive filamentous growths has not been established.

Despite Hawkes' (10) statement to the contrary, fungus filaments are frequently seen in normal activated sludge. Lackey and Smith (12) speculated that, in some cases, the mechanism of flocculation could be the adherance of bacteria to the exterior of fungus mycelium. Extensive growths of the filamentous fungus Geotrichum candidum have been associated with bulking sludge in a few instances (10).

The significance of the size of the activated sludge floc particles has been a question which has had some consideration. Mueller et al (14) reviewed the various techniques which have been employed in four different investigations for determining floc particle size. The particle size distribution is usually found to fit the log-normal curve. The size of the floc particles may be related to the available oxygen supply but so far no relationship between plant performance and particle size has been established.

It is evident that a great deal of information about activated sludge can be obtained by microscopic examination. Undoubtedly, some of this information can be related to the condition of the sludge and the condition of the sludge should have a great influence on plant performance. Also, it should be possible to use information about sludge condition to predict the approach of operating problems before they occur. The previous investigations in which microscopic examination has been used to acquire information about sludge condition have concentrated on one aspect or another of the sludge appearance and the investigations have been limited to samples from only one or a few activated sludge plants. Therefore, generalizations which apply to all types of activated sludge processes are difficult to make.

The information contained in this report was compiled by microscopic examination of 64 different samples of activated sludge from 19 different treatment plants. The purpose of presenting the material in this form is to provide a basis for discussion of the relationships which can be developed between the microscopic appearance of the sludge and plant performance. It is hoped that this atlas will provide a reference by which plant operators can compare the types of sludge which occur in their plants with the types of sludge produced in other plants and stimulate further consideration and investigation of the biology of activated sludge.

Methods

The methods employed in obtaining the information used to assemble this atlas have been described in detail elsewhere (15). They will be summarized briefly to provide a background for the succeeding discussion.

Nineteen different activated sludge plants in Illinois, Indiana, and Wisconsin were sampled periodically over a two-year period. Fifteen of these plants were sampled four times, once each season of the year. Four of them were sampled only once. Grab samples of the mixed liquor, return sludge, raw sewage, settled sewage, and effluent were obtained each sampling trip. Information about the sizes of the various units in the treatment plant and operating data on the plant were obtained from the plant superintendent. The samples were transported back to the laboratory for analysis. The chemical and physical analyses were performed using the procedures in Standard Methods (16).

The microscopic examination of the sludge samples was accomplished using a Neubauer haemocytometer. Samples of the mixed liquor were diluted anywhere from one to one to one to eight, depending upon the solids concentration in the mixed liquor. A drop of the diluted sludge was placed on each grid of the haemocytometer and covered with a glass coverslip. The sludge particles and filaments were counted using a phase contrast microscope at 200x magnification. Particle sizes were estimated by making comparison with the smallest division on the chamber grid. The smallest size used in grading particles was a square one-sixteenth of a millimeter on each side or 3906.2 square microns in area. All particles were then graded according to whole number multiples of the smallest size unit. A range of one through eight was used.

The particle counts and filament counts in each of the eight size ranges were plotted on histograms. The data from the histograms were then plotted on log-probability paper to determine if the distribution would fit the log-normal distribution. In most cases it did.

In addition to particle sizing and counting, the samples were scanned to determine the other microscopically observable features. These included the numbers and types of protozoa and other invertebrates present, the types of floc particles, the presence or absence of fungus mycelia, and the presence and appearance of any free bacterial cells. Photomicrographs of each sample were made using a Polaroid M-2 Industrial Camera.

Samples of the mixed liquor were streaked on a number of different solidified bacteriological and mycological media. The streaks were examined periodically over a four-week period to determine which types of filamentous organisms were present. Although a variety of media were used, there were still some filamentous organisms which would not grow and therefore could not be isolated and identified. The isolations and identifications of the filamentous organisms were performed using standard bacteriological and mycological techniques, as described in Bergy's Manual (17), Skerman's Guide to the Identification of the Genera of Bacteria (18), Cooke's Laboratory Guide to Fungi in Polluted Waters, Sewage, and Sewage Treatment Systems (19), and Barnett's Illustrated Genera of Imperfect Fungi (20).

Microscopic Appearance of Sludge

This atlas of activated sludge types is presented in the form of photomicrographs of the sludge samples which were collected and examined. Two photomicrographs at different magnifications of each sludge sample are included. Each photomicrograph has a micron scale so that measurements of the size of the floc particles and of the organisms described can be made directly. On the page facing each pair of photomicrographs is a compilation of some of the data which were collected by examination of the sludge sample depicted.

The information which can be obtained from microscopic examination of activated sludge included the form and appearance of the floc particles, the extent of growth of the filamentous organisms present, the numbers of free individual bacterial cells present, the presence or absence of spirochaetes, the types and numbers of protozoa present, and the types and numbers of invertebrates. All of this information should be useful for determining the condition of the sludge if it were properly integrated.

Floc particles may be described as being compact, ragged, tassel-like, lobate, or zoogleal. Compact floc particles were found in 24 out of the 64 sludge samples and nine of these 24 samples had extensive filamentous growths as well as compact floc particles. Examples of compact floc particles without filaments can be found on pages 15, 27, 67, 99, and 113. Compact floc particles with filaments are shown in the photomicrographs on pages 7 and 93. Most of the ragged floc particles have rather extensive filamentous growths, as shown in the photomicrographs on pages 21, 29, 39, 63, and 107. Tassel-like floc particles which have previously been described as being associated with poor plant performance (10) were encountered only once in this set of samples and these are shown in page 125. Sludge with lobate floc structure was also encountered only once and this sample is pictured on page 5.

Previously there has been some controversy about the significance of *Zoogloea ramigeria* in activated sludge with opinions ranging all the way from the idea that *Zoogloea* were the bacteria primarily responsible for conversion of the organic matter in sewage into a settleable form to the concept that *Zoogloea* was not a valid genus but a growth form of a number of different bacteria. In these samples, *Zoogloea* appeared several times and it is best pictured in the photomicrograph on page 59. *Zoogloea* was not always present and when it was present it made up only a small fraction of the total number of particles. Thus, from our experience, it appears that *Zoogloea* is a morphologically recognizable genus but that it does not have any great significance in the processes which are sampled.

Several forms of filamentous growths were found in the samples examined. The most readily recognized type of filamentous bacteria in activated sludge are the actinomycetes which grow as very short, highly branched filaments such as those in the photomicrographs on pages 55, 57, 87, and 89. However, since the diameter of the actinomycete filaments is very small, very high magnification is necessary. All of the actinomycetes which were isolated and identified belonged to the genus *Nocardia*. Although *Nocardia* were isolated from every sample of sludge which was examined, they were present in large enough numbers to be found by microscopic examination in only a few of the samples. The only samples in which *Nocardia* could be detected by microscopic examination were samples from plants treating dairy wastes or from extended aeration processes. Actually, the plants treating dairy wastes had very long aeration periods. It may be speculated that since *Nocardia* are a very slow-growing bacteria, they would only be found in activated sludge processes with very long aeration periods. They do not become incorporated into the sludge particles but grow as separate colonies. These colonies do not settle very rapidly and they have a tendency to accumulate in foam on the aeration tank.

One morphologically distinct filamentous bacterium was found in two samples from the Hanover Park Plant and is pictured on pages 115 and 117. This organism was not isolated but was identified as *Caryophanon* on the basis of morphology alone. *Caryophanon* are the very long filaments in which the cells run across the long axis of the filaments. The sludge samples pictured on pages 115 and 117 had several other types of filamentous bacteria present but all of the other bacterial filaments have a much smaller diameter.

The other filamentous bacteria were not identifiable on the basis of their morphology in the sludge samples alone. In some samples of activated sludge the floc particles appeared to be composed entirely of filamentous bacteria. These samples are pictured on pages 35, 41, 81, and 117. Other samples which were very filamentous had the filaments extending directly out from well-formed floc particles, as shown on pages 7 and 75. In several of the samples, pictured on pages 45, 47, 63, 97, and 121, the long bacterial filaments were coiled up together into bundles.

Whether the filaments were extending directly out from the floc particles or were coiled up together had an effect on the settling properties of the sludge. When the filaments were extending directly out from the sludge particles, the sludge volume index was much greater than when the filaments were coiled up together. In laboratory experiments it was found that the addition of a small amount of sugar to sludge samples with coiled-up filaments would cause the filaments to uncoil and extend out from the floc particles. This uncoiling of filaments was accompanied by a very rapid increase in the sludge volume index. A sludge sample which contains large numbers of coiled-up bacterial filaments can be considered to have an unstable sludge volume index; that is, a small change in the soluble material present in the liquid can cause a very large change in the sludge volume index.

Filaments which could be recognized as fungus were found in several of the sludge samples. The sample from Fox River Grove which is pictured on page 127 consisted mostly of fungus mycelia and some very small bacterial flocs. Other examples of fungus mycelia are shown on pages 51, 53, 95, and 99. Fungi definitely are present in activated sludge but their role in the process has not yet been determined.

Individual bacterial cells free of the floc particles were found in many of the samples examined. In most cases these cells were short rods, as pictured on pages 9, 31, 33, 59, 73, 81, and 97. In some of the samples, the free bacterial cells were spirochaetes. Spirochaetes are long, cork-screw shaped bacteria cells and can be seen in the photomicrographs on pages 15, 17, 77 and 81. The degree of flocculation (how well the sludge is flocculated) depends upon the numbers of free bacterial cells in relation to the size of the floc particles. It is generally believed that a well flocculated sludge will be produced in an activated sludge process having a low loading intensity or, in other words, the greater the concentration of soluble organic matter the greater the numbers of free bacterial cells. This seemed to be the case in the samples which we examined. However, it is only the rod-shaped bacteria which are involved in the flocculation phenomena. The presence or absence of spirochaetes did not seem to correlate with any other parameters which we calculated.

The protozoa which are commonly found in activated sludge belong to three different classes; Rhizopoda, Flagellata, and Ciliata. The rhizopods are irregularly shaped cells which change shape as they crawl around on a surface. They have many cellular inclusions (nucleus, food vacuoles, etc.) which can be seen under the microscope. The flagellates have long, slender, hair-like structures (flagella) extending directly out from the cell and they use the flagella to swim rapidly through the floc particles. The ciliates have a large number of short hair-like protrusions which are used for swimming. Two types of ciliates are easily recognized, the free-swimming ciliates which have cilia covering the entire surface of the cell and the stalked ciliates which grow in colonies on branched stalks and have only a ring of cilia around one end of each cell. The Rhizopoda were represented mostly by different forms of amoeba such as the one which can be seen in the upper photomicrograph on page 9. There is also a stalked ciliate in the same photomicrograph but a better picture of a stalked ciliate is shown on page 19 on which are presented pictures of the same organism at two different magnifications. Free-swimming ciliated protozoa were found less frequently than the other types of protozoa. A good example of a single free-swimming ciliate is shown in the photomicrograph on page 69 in which the motion of the cilia is clearly depicted. The photomicrograph on page 71 shows several free-swimming ciliates mixed in with floc particles.

The most frequently observed protozoa were the flagellates. The photomicrograph on the bottom of page 35 shows five flagellates and the flagella can be clearly distinguished among the filamentous bacteria. The photomicrograph on page 83 shows several flagellates swimming in among floc particles.

The invertebrates which were commonly found in the samples examined are rotifers and nematodes. Nematodes are microscopic worms which have a snake-like appearance when magnified, such as the one shown on page 39. Rotifers are microscopic animals which have a ring of cilia round their mouths. The cilia are used for swimming and also for trapping bacterial cells which they eat. Rotifers are always larger than protozoa. A single rotifer is shown in the upper photomicrograph on page 25.

A great deal of information about activated sludge can be obtained by microscopic examination. At the present time, this information is poorly organized and not particularly useful for plant control and analysis of operating problems. The organization of this information and its correlation with operating problems will require a great deal of work. The approach to this work will be to classify types of operating problems, to accumulate a large number of observations of sludge samples for the various types of problems, and to correlate the microscopic description of the sludge with the types of operating problems.

Description of Sludge Types

The plants which were sampled were selected to include a large proportion of plants which have a history of operating problems. The particular operating problems considered in this project were bulking, deflocculation, and pin point floc.

The classification of these operating problems was made on the basis of the settleability test, determination of the suspended solids in the supernatent from the settleability test, and the mixed liquor suspended solids test. Sludge samples which had a sludge volume index of less than 100 ml/gm and a supernatent suspended solids concentration of less than 30 mg/l were considered to be normal samples. Sludge samples with a sludge volume index of greater than 100 ml/gm and a supernatent suspended solids of less than 30 mg/l were classified as bulking with those samples having a sludge volume index of greater than 300 ml/gm considered to be severe bulking. Samples having a supernatent suspended solids of greater than 30 mg/l were either deflocculated or had pin point floc. The difference between deflocculated sludges and those having pin point floc was determined on the basis of the appearance of the supernatent. Deflocculated sludges show a uniform turbidity in the supernatent while pin point floc appear as discrete particles suspended in a clear liquid. The classification of the sludge types from the 64 different trips is given in Table I.

Of the 64 sludge samples, 12 were classified as normal, 16 as pin point floc, 19 as bulking, and 17 as deflocculated. Some of the information which can be obtained by microscopic examination is tabulated in Table II. Also included in this table are some data on the average process loadings and process performances for each type of sludge.

Particle size distribution was log normal for 61 out of the 64 samples examined. The average particle sizes are given in projected area. An equivalent linear dimension for the particle sizes could be obtained by taking the square root of the area. Normal sludges and bulking sludges had about the same average particle size and particle size distributions. Sludges with pin point floc had, on the average, much smaller particles than the normal sludges. The size of the particles counted in the deflocculated sludges was about the same as that of the normal sludges. However, all of the deflocculated sludges had large numbers of free bacterial cells which were not counted as particles. If these individual cells had been counted, the average particle sizes for the deflocculated sludges would have been extremely small.

There does not appear to be much difference between the processes which produce normal sludge and those which produce pin point floc on the basis of either process loading or process performance. Apparently the solids lost from the process when pin point floc are produced are relatively stable and have a low oxygen demand rate. Bulking sludges also occur in the same loading range as normal sludges. However, on the average, they give significantly better process performance. Of course, if sludge is lost from the secondary settling tank when bulking occurs, the performance of the process deteriorates considerably. All of these samples of bulking sludges were collected from plants which were operated so as not to lose sludge. The plants producing deflocculated sludges had a higher average loading than the other plants. However, some of the plants with deflocculated sludges had relatively low loadings. It appears that a high loading can cause deflocculation but that there are other causes also. The performance of a process with deflocculated sludge is definitely poor.

Filamentous members of the genus Bacillus were the most frequently found filamentous organisms in all types of sludges examined. Actually, filamentous Bacillus was found in all the sludges examined but they were found in large numbers in only about two-thirds of the samples. Actinomycetes (mostly members of the genus Nocardia) were also present in all sludge samples but occurred in large numbers in only one-third of the samples examined, none of which were normal samples. Sphaerotilus was found in large numbers in 11 of the 64 samples but was not any more prevalent in bulking sludges than in normal sludges. Beggiatoa was found in large numbers in only seven of the sludge samples but these seven samples all showed one of the three settling problems. The filamentous bacterium which did show up more often in bulking sludges than in the other types was a member of the genus Arthrobacter.

From these data, it is evident that the filamentous bacteria which can be isolated in large numbers from activated sludge belong to the genera

Bacillus, Arthrobacter, Sphaerotilus, Beggiatoa and Nocardia. Other filamentous bacteria are sometimes present but as yet have not been isolated from sludge samples. Bacillus and Nocardia are almost always present in activated sludge and often in large numbers. Sphaerotilus and Beggiatoa are sometimes present and often associated with settling problems. Arthrobacter is occasionally present and usually associated with bulking or deflocculation. Any given sample of bulking or deflocculated sludge will usually contain a variety of different types of filamentous organisms and it would be quite difficult to determine which one is most important in causing the problem.

Stalked ciliates were found in large numbers in 45 of the 64 samples and their presence or absence did not correlate with any of the settling problems or with plant performance. Free-swimming ciliates were so infrequently present that they do not appear to have any particular significance in the activated sludge process. Flagellates and Rhizopods were present less frequently than stalked ciliates but did not evidence any association with settling problems or with poor performance.

Rotifers were present in large numbers in 32 of the 64 samples. They were conspicuously absent from the deflocculated sludges but were present in about equal proportions in normal sludge samples, samples showing pin point floc, and bulking samples. If there was any indication of an association of rotifers with a particular sludge type, it was with the bulking sludges. The possible association of rotifers with bulking sludges and the definitely better performance of the bulking sludges may indicate a connection between the presence of rotifers and good performance. When the sludges are classified according to the presence or absence of large numbers of rotifers, it is found that the sludges having large numbers of rotifers have an average effluent BOD of 16 mg/l and an average loading of 0.164 lbs BOD/day/lb MLSS. The samples which had few or no rotifers had an average effluent BOD of 74 mg/l and an average loading of 0.269 lbs BOD/day/lb MLSS. It is obvious that for these samples at least, the presence of rotifers in large numbers is associated with lower loading and better performance.

More studies will be required before it is possible to relate generally sludge condition or process performance to the presence or absence of specific organisms. Many different filamentous organisms are present in activated sludge and any one or combination of several of them can be associated with bulking. Various groups of protozoa are present in activated sludge and undoubtedly they do perform important functions in a well operated process but none appear to be useful as indicators of sludge condition. Rotifers definitely are associated with good plant performance and they appear to be the group which will be most useful as indicator organisms.

TABLE I

CLASSIFICATION OF SLUDGE TYPES

Plant Location	Trip Number	Season	SVI (ml/gm)	Supernatent SS (mg/l)	Classification
West Chicago	3	Su	93	53	Deflocculated
	5	F	77	32	Normal
	23	Sp	223	22	Bulking
	44	W	108	236	Deflocculated
Chicago, N.S.	6	F	125	28	Bulking
	30	Su	80	47	Pin point floc
	48	W	78	41	Pin point floc
	55	Sp	84	26	Normal
Fort Wayne	7	F	346	16	Bulking
	21	Sp	412	6	Bulking
	50	W	139	46	Deflocculated
	64	Su	119	19	Bulking
McHenry	8	F	78	28	Normal
	28	Su	547	16	Bulking
	46	W	83	48	Pin point floc
	53	Sp	100	38	Normal
Milton	9	F	82	51	Deflocculated
	22	Sp	148	48	Deflocculated
	42	W	250	63	Deflocculated
	60	Su	946	16	Bulking
Brookfield	10	F	676	3	Bulking
	19	Sp	161	-	Bulking
	43	W	548	12	Bulking
	61	Su	100	28	Normal
Woodstock	11	F	38	59	Pin point floc
	25	Su	50	66	Pin point floc
	47	W	65	46	Pin point floc
	51	Sp	67	43	Pin point floc
Gages Lake	12	F	189	-	Bulking
	27	Su	146	40	Deflocculated
	45	W	245	37	Deflocculated
	52	Sp	120	21	Bulking
Libertyville	13	W	51	32	Pin point floc
	24	S	38	20	Normal
	40	F	82	32	Pin point floc
	62	Su	42	74	Pin point floc
Spinney Run	14	W	163	266	Deflocculated
	20	Sp	59	11	Normal
	31	Su	263	73	Deflocculated
	37	F	36	178	Deflocculated

continued

TABLE I (continued)

CLASSIFICATION OF SLUDGE TYPES

Plant Location	Trip Number	Season	SVI (ml/gm)	Supernatent SS (mg/l)	Classification
Borden's	15	W	115	303	Deflocculated
	32	Su	199	200	Deflocculated
	38	F	150	181	Deflocculated
	58	Sp	122	-	Bulking
Antioch	16	W	79	110	Pin point floc
	26	Su	54	36	Pin point floc
	39	F	46	21	Normal
	54	Sp	296	9	Bulking
North Shore Clavey Road	17	W	44	62	Pin point floc
	34	Su	36	72	Pin point floc
	36	F	41	23	Normal
	59	Sp	42	88	Pin point floc
Gary	18	W	274	-	Bulking
	29	Su	42	90	Deflocculated
	35	F	42	74	Pin point floc
	56	Sp	102	11	Normal
Hanover Park	41	F	123	25	Bulking
	49	W	336	9	Bulking
	57	Sp	141	-	Bulking
	63	Su	156	17	Bulking
Carol Stream	1	Su	47	65	Deflocculated
Crystal Lake	2	Su	67	39	Pin point floc
Fox River Grove	4	F	159	47	Deflocculated
Chicago, WSW	33	Su	86	15	Normal

TABLE II

PREDOMINANT ORGANISMS IN DIFFERENT SLUDGE TYPES

Classification	No. of Samples	No. Collected Each Season				Avg. Particle Size (u^2)		Avg. Processes Loading (lbs BOD/lb MLSS/day)		Avg. Plant Performance	
		Sp	Su	F	W	Range	Avg	Range	Avg	Eff BOD(mg/l)	BOD Red(%)
Normal	12	6	1	5	0	2800-7600	4900	.027-.313	.177	25	80
Pin point floc	16	2	6	2	6	100-6100	2700	.018-.782	.181	24	77
Bulking	19	6	5	5	3	1100-7200	4600	.068-.456	.202	17	86
Deflocculated	17	1	6	4	6	600-5800	4100	.084-1.10	.312	115	60

	Predominant Filamentous Bacteria[1]					Predominant Protozoa[2]					Invertebrates Present		
	Bac.	Arth.	Sph.	Beg.	Nocardia	St. C.	F.C.	Flag.	Amoeba	None	Rotifers	Nematodes	None
Normal	8	1	4	0	0	9	1	6	2	0	6	2	5
Pin point floc	8	0	1	2	6	11	2	6	4	2	10	1	6
Bulking	12	7	4	2	6	15	1	12	6	0	13	0	6
Deflocculated	8	3	2	3	6	10	0	13	3	1	3	0	14

[1] Bac. = *Bacillus*
Arth. = *Arthrobacter*
Sph. = *Sphaerotilus*
Beg. = *Beggiatoa*

[2] St. C. = Stalked ciliates
F.C. = Free-swimming ciliates
Flag. = Flagellates

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